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Welcome to the Prairie Feed Resource Centre Database

Welcome to the Prairie Feed Resource Centre Database on feedstuffs grown or produced in western Canada. The purpose is to provide to those accessing the database a detailed, yet brief description of the feeds to provide for their commerce and use in diets. The information presented is a compilation of research and feed evaluation work in western Canada by nutritionists, researchers and extension personnel.

Support for the establishment of the database was received through the Saskatchewan Agricultural Development Fund and the Canada-Saskatchewan Agri-Food Innovation Fund. The Prairie Feed Resource Centre's feed industry members provide ongoing support for operations, while technical support is present from the University of Saskatchewan's scientific community, in particular the Department of Animal and Poultry Science.

The Prairie Feed Resource Centre located at the University of Saskatchewan is the INFIC centre for Canada and is located in Canada's largest feed production area.

The feed database was developed to provide unbiased information in a form for multiple uses. This database was made possible with the specific contributions of David A. Christensen, dairy and ruminant nutrition researcher; John J. McKinnon, beef and ruminant nutrition researcher; Henry L. Classen, poultry nutrition researcher; G. Leigh Campbell, non ruminant nutrition researcher; Phil A. Thacker, swine nutrition researcher; M.D. Drew aquaculture nutritionist, and Vernon J. Racz, nutritionists all of the Department of Animal and Poultry Science and Prairie Feed Resource Centre at the University of Saskatchewan.

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Table of Contents

CEREAL GRAIN CROPS
BARLEY GRAIN (*Hordeum Vulgare*) 01
OAT GRAIN (*Avena Sativa*) 10
RYE GRAIN (*Secale Cereale*) 18
TRITICALE GRAIN 23
WHEAT GRAIN (*Triticum Aestivum*) 29

OILSEEDS AND OILSEEDS MEALS
CANOLA MEAL 37
WHOLESEED CANOLA (*Brassica Campestris*) 45
FEEDING FROST-DAMAGED CANOLA SEED 47
FLAXSEED (*Linium Usitatissimum*) 50
LINSEED (*Linum Usitatissimum*) Meal 53
SUNFLOWER (*Helianthus Annuus*) SEED AND MEAL 57

PULSE AND SPECIALTY CROPS
CHICKPEA (*Cicer Arietinum*) 66
FABA BEANS (*Vicia Faba*) 71
FIELD PEAS (*Pisum Sativum*) 77
LENTILS (*Lens Culinaris*) 83
CANARY SEED (*Phalaris Canariensis L.*) 87

ANIMAL BY-PRODUCTS
BLOOD MEAL 90
FEATHER MEAL 95
FISH MEAL 98
MEAT AND BONE MEAL 102

PLANT BY-PRODUCTS
CHAFF 108
GRAIN SCREENINGS 110
OAT HULLS 114
BREWERS' GRAIN 117
DISTILLERS BY-PRODUCTS 121
MOLASSES 126

FORAGE CROPS
FORAGE QUALITY AND FEED ANALYSIS 129

PROCESSED ALFALFA PRODUCTS
DEHYDRATED PELLETS, SUN-CURED PELLETS, AND ALFALFA CUBES 130

FORAGE HAY CROP
ALFALFA (*Medicago Sativa L.*) HAY 138
BARLEY HAY 142
OAT HAY 145
RYE HAY 148
TRITICALE HAY 151
WHEAT HAY 152

GRASS AND GRASS HAYS
CRESTED WHEATGRASS (*Agropyron Desertorum L.*) 155
MEADOW BROMEGRAS (*Bromus Riparius*) 158
SAINFOIN (*Onobrychis Viciifolia*) 161
NATIVE HAY 164
BROMEGRASS HAY 166
SLOUGH HAY 169

SILAGE
BARLEY (*Hordeum Vulgare*) SILAGE 171
CORN (*Zea Mays*) SILAGE 176
OAT (*Avena Sativa*) SILAGE 181
RYE (*Secale Cereale*) SILAGE 185
TRITICALE SILAGE 190
WHEAT (*Triticum Aestivum*) SILAGE 194
ALFALFA (*Medicago Sativa*) SILAGE 197
BROMEGRASS SILAGE 202

CEREAL STRAWS AND CROP RESIDUES AS FORAGE
STRAW 205
BARLEY STRAW 206
OAT STRAW 209
RYE STRAW 212
TRITICALE SRAW 215
WHEAT STRAW 216
CROP RESIDUES AS FORAGES 219

CEREAL GRAIN CROPS

BARLEY GRAIN (*HORDEUM VULGARE*)

General Agronomics

Barley, as a cereal grain, is usually grown in temperate to sub-arctic climates (Anderson and Schroeder 1999). Barley has the ability to adapt to stressful growing conditions such as drought and saline soils (Edney et al. 1992). Natural variations in the chemical composition of and the nutritional value of barley occur as the result of harvesting conditions and environmental factors such as soil, weather, and disease (Bell 1987). Barley can be used for forage, silages and hays, and as a grain present in hulled kernel varieties and now more recently also as hulless kernel varieties. Table 1 shows the production of barley in western Canada with approximately 92.5% of Canadian barley being produced in this area (Statistical Handbook 2000).

Table 1. Production of barley grain in western Canada from 1997 to 2000

	Thousands of tonnes			
	1997	1998	1999[r]	2000[p]
British Columbia	84.9	103.4	89.3	88.8
Alberta	6270.5	5660.8	5987.4	5388.7
Saskatchewan	4430.7	4310.9	4942.3	5477.9
Manitoba	1685.2	1630.8	1214.9	1622.0
Canadian total	13527.3	12708.7	13196.0	13468.1

[r] Revised

[p] Preliminary

Source: Canadian Grains Institute, Statistical Handbook 2000.

Nutrient Composition and Behavior

The crude protein content of barley is higher than that of corn and similar to other feed grains, although it contains slightly lower energy than corn, partly due to its fibrous hull (Lardy and Bauer 1999). Barley contains more lysine than corn and therefore, less supplemental lysine is needed when feeding barley (Canadian International Grains Institute 1993). The starch content of barley is 64.6% as compared to corn at 71.9%, wheat at 63.8% and oats at 44.7% (Waldo 1973, as quoted from Anderson and Schroeder 1999). The fat (E.E.) content of 2.09%, on a dry matter basis, is similar to other cereals such as wheat but lower than that of corn. This lower fat content and higher fibre content from the hulls is the main reason for lowered energy compared to corn.

Hulless barley varieties are becoming more popular because of the improved nutrient quality. Hulless barley's have been developed through existing hulled barley lines, which were conventionally bred to have a loose fitting hull. In the harvesting process the threshing unit removes the loose hull leaving a barley kernel with a bran

covering. The crude protein of hulless barley is higher than hulled barley and similar to that of wheat (Prairie Feed Resource Center (PFRC) 1999). However, studies have shown that as the protein content increases, certain amino acids do not increase in proportion, thus quality decreases (Rhodes and Jenkins 1975, as quoted by Edney et al. 1992). Tables 2 and 3 illustrate the amino acid content and characteristics of hulled and hulless barley, respectively, and the regression equations for predicting amino acids are shown in Table 4. Hulless barley has a higher starch content than hulled barley and therefore has an increased energy content (PFRC 1999; Edney et al. 1992). The crude fibre content of hulless barley is less than hulled barley and consequently the ADF is also lower, allowing greater utilization by non-ruminants. Hulless barley contains a lower ash content than hulled barley and only minor differences are found in terms of fat content. Tables 5 and 6 represent the chemical composition and characteristics of hulled and hulless barley.

Table 2. Amino acid and protein characteristics of barley grain (100% DM basis)

Amino Acid	Average Amount (%DM)[1]	Swine % Apparent Ileal Digestibility[2]	Swine % True Ileal Digestibilty[2]	Poultry % True Ileal Digestibiliy[2]
CP level (%)	12.70			
Arg	0.61	77	87	87
His	0.28	77	87	91
Ile	0.44	72	84	88
Leu	0.87	76	87	88
Lys	0.46	64	79	80
Met	0.22	78	85	85
Cys	0.31	73	84	84
Phe	0.62	79	87	90
Tyr	0.33	74	87	88
Thr	0.39	60	81	84
Trp	0.12			
Val	0.58	69	82	84

[1] NRC, Nutrient Requirements of Swine 1998.
[2] Rhone-Poulenc Animal Nutrition 1993.

Table 3. Amino acid values of hulless barley (100% DM basis)[1]

Amino Acid	Average Amount (%DM)
CP level (%)	16.93
Arg	0.64
His	0.26
Ile	0.47
Leu	0.88
Lys	0.50
Met	0.18
Cys	0.27
Phe	0.69
Tyr	0.45
Thr	0.45
Trp	0.15
Val	0.63

[1] NRC, Nutrient Requirements for Swine 1998.

Table 4. Regression equations for predicting amino acid levels in barley from crude protein content[1]

Amino Acid	Equation	R Value
Lysine	%CP X 0.0235 + 0.1330	0.83
Methionine	%CP X 0.0152 + 0.0190	0.92
Methionine + Cystine	%CP X 0.0301 + 0.1010	0.89
Tryptophan	%CP X 0.0095 + 0.0230	0.88
Threonine	%CP X 0.0299 + 0.0440	0.96

[1] Degussa Company 1988.

USES IN LIVESTOCK AND POULTRY DIETS

Poultry

Zhi-Yuan et al. (1995) compared the effects of feeding two types of hulless barley, Condor and CDC Richard, on broiler chick performance. The average chemical analyses of the two cultivars were similar for crude protein, acid detergent fibre, starch, and other analyses. As the crude protein in the diet increased, feed conversion tended to be poorer, although not significantly. It is speculated that as the crude protein levels in barley increase, the quality of the protein is compromised. Table 7 illustrates the similar body weights and feed conversion exhibited by broilers when fed either type of hulless barley at different crude protein levels. No significant differences were noted with respect to either characteristic.

Classen et al. (1988) found that hulless barley could be incorporated into laying hen diets at levels up to 80 percent. Birds fed this level of hulless barley had similar egg production and body weights as those fed 0 percent. When birds were fed diets containing 80% hulless barley, feed consumption was significantly reduced, although feed conversion was improved. Egg weight and specific gravity of eggs were improved when birds were fed 80% hulless barley, suggesting that levels as high as this can be fed to laying hens without altering bird performance.

Barley grains (hulled and hulless varieties) contain some of their carbohydrates in the form of β-glucans. These β-glucans are difficult for poultry to digest and gut viscosity is increased leading to interference also with other nutrient absorption. It is standard practice now to include the enzyme β-glucanase in barley based feedstuffs for poultry to enhance digestibility.

Table 5. Nutrient composition and characteristics of barley grain (100% DM basis)

Nutrient	Average	SD
CP (%DM)[1]	12.40	
RDP (%CP)[2]	66.93	
RUP (%CP)[2]	33.07	
ADFIP (%DM)[2]	0.66	
NDFIP (%DM)[2]	1.06	
SP (%CP)[2]	17.0	
NPN (%SP)[2]	29.0	
CF %[3]	5.7	
ADF %[1]	6.61	
NDF %[1]	21.21	
Lignin (%DM)[2]	1.91	
Cellulose (%DM)[3]	5.00	
Starch (%)[1]	59.25	
NFC[4]	61.12	
A kd (%/hr)[2]	300.0	
B_1 kd (%/hr)[2]	30.0	
B_2 kd (%/hr)[2]	5.0	
DE (kcal/kg) (swine)[3]	3534.0	
TDN% (ruminants)[2]	84.0	
ME (kcal/kg) (poultry)[5]	3153.0	
ME (kcal/kg) (swine)[5]	3400.0	
NEm (Mcal/kg) (beef)[2]	2.06	
NEg (Mcal/kg) (beef)[2]	1.40	
NEl (Mcal/kg) (dairy)[3]	1.94	
Fat (EE) %[1]	2.09	
Ash %[1]	2.97	
Calcium %[6]	0.09	0.03
Phosphorus %[6]	0.37	0.08
Sodium %[3]	0.03	
Magnesium %[6]	0.14	0.04
Copper (mg/kg)[6]	7.06	2.24
Manganese (mg/kg)[6]	17.81	4.35
Iron (mg/kg)[6]	87.63	43.00
Zinc (mg/kg)[6]	33.69	6.42
Selenium (mg/kg)[6]	0.31	0.20

[1] Prairie Feed Resource Center - variety CDC Kendall hulled, averaged over 2 years at 2 sites.

[2] NRC, Nutrient Requirements for Beef Cattle 1996.

[3] NRC, United States-Canadian Tables of Feed Composition 1982.

[4] NFC equations, NRC, Nutrient Requirements of Dairy Cattle 2001.

[5] Rhone-Poulenc Animal Nutrition 1993.

[6] Saskatchewan Feed Test Laboratories, Average over 1974-1982, 1986, 1988, and 1990.

Table 6. Nutrient composition and characteristics of hulless barley (100% DM basis)

Nutrient	Average
CP (%DM)[1]	14.45
RDP (%CP)[?]	
RUP (%CP)[?]	
ADFIP (%DM)[?]	
NDFIP (%DM)[?]	
SP (%CP)[?]	
NPN (%SP)[?]	
CF %[?]	
ADF %[1]	2.62
NDF %[1]	15.06
Lignin (%DM)[?]	
Cellulose (%DM)[?]	
Starch (%)[1]	63.21
NFC[?]	
A kd (%/hr)[?]	
B_1 kd (%/hr)[?]	
B_2 kd (%/hr)[?]	
DE (kcal/kg) (swine)[2]	3828.0
TDN % (ruminants)[3]	87.1
ME (kcal/kg) (poultry)[?]	
ME (kcal/kg) (swine)[2]	3772.0
NEm (Mcal/kg)[3]	2.22
NEg (Mcal/kg)[3]	1.51
NEl (Mcal/kg)[3]	2.02
Fat (EE) %[1]	2.11
Ash %[1]	2.20
Calcium %[2]	0.05
Phosphorus %[2]	0.51
Sodium %[2]	0.02
Magnesium %[2]	0.14
Copper (mg/kg)[2]	5.68
Manganese (mg/kg)[2]	18.18
Iron (mg/kg)[2]	63.63
Zinc (mg/kg)[2]	30.68

[1] Prairie Feed Resource Center - results are based on an average of 5 different varieties over 2 years at 2 different sites.

[2] NRC, Nutrient Requirements of Swine 1998.

Table 7. Body weight and feed conversion of chicks fed Condor or CDC Richard hulless barleys varying in protein content[1]

	Body weight (g)			Feed:gain		
CP (%)	7 days	14 days	21 days	7 days	14 days	21 days
Condor						
12.4	127	300	635	1.30	1.45	1.50
13.4	136	339	669	1.33	1.53	1.67
14.1	136	299	601	1.28	1.54	1.59
14.3	124	281	593	1.35	1.54	1.50
15.0	137	296	603	1.30	1.58	1.60
Mean	132.2	303.0	620.3	1.314	1.528	1.569
CDC Richard						
12.7	135	320	674	1.34	1.55	1.59
13.3	140	232	660	1.29	1.45	1.56
14.4	130	288	604	1.30	1.57	1.53
14.8	127	279	578	1.37	1.69	1.65
15.3	127	287	609	1.37	1.61	1.62
Mean	131.7	299.4	625.0	1.334	1.574	1.592
SEM	1.9	7.2	10.9	0.009	0.220	0.019

[1] Adapted from Zhi-Yuan et al 1995.

[2] There were no significant differences (P>0.10) in body weight or feed/gain between chicks fed Condor or CDC Richard hulless barleys.

Swine

In 1976, Mitchall et al. evaluated animal performance and digestibility of hulless and hulled barley varieties in weanling pig diets. Two types of hulled and hulless varieties of barley were used and compared to an average of five wheat samples. No significant differences were found between growth rates, feed intake, and feed efficiency among all the diets (Table 8). The first digestibility trial revealed that protein digestibilities tended to be poorer for barley fed pigs when compared to pigs fed wheat, but there were no differences noted between the barley samples (Table 9). The dry matter digestibility was higher for the hulless barley than the covered barley and was similar to wheat. No differences were found in energy digestibility between diets. However, the second trial indicated poor protein digestibility for hulless barley when compared to hulled varieties. The opposite occurred for dry matter and energy digestibilities, whereby the hulless barley had higher digestibility coefficients than the covered varieties. Hulled barley can be fed to all classes of swine at levels up to 80% and hulless barley can be fed at levels approaching 90% of the total diet.

Table 8. Growth and feed utilization of pigs from 22 to 55 kg[1]

Treatment	Average daily gain (kg)	Daily feed intake (kg)	Feed:gain ratio
CB A[2]	0.65	1.58	2.41
CB B	0.67	1.60	2.41
HB A	0.60	1.46	2.44
HB B	0.59	1.45	2.47
Wheat	0.59	1.47	2.50

[1] Adapted from Mitchall et al. 1976.

[2] CB denotes covered barley and HB denotes hulless barley; A and B denote different barley varieties.

Table 9. Digestibility coefficients for dry matter, crude protein, and energy in diets[1]

Treatment	Apparent Digestibility (%)		
	Dry Matter	Protein	Energy
Trial 1			
CB-A[2]	74.4*bc*[3]	74.7*b*	74.3
CB-B	73.3*c*	71.6*b*	72.1
HB-A	80.4*ab*	70.7*b*	78.4
HB-B	78.8*bc*	68.6*b*	76.2
Wheat	80.4*ab*	31.4*a*	79.2
Trial 2			
CB-A	79.5*b*	79.6*a*	79.2*b*
CB-B	77.2*b*	79.0*a*	76.2*c*
HB-A	83.7*a*	74.8*b*	81.8a

[1] Adapted from Mitchall et al. 1976.

[2] CB denotes covered barley and HB denotes hulless barley.

[3] Means in the same column, within trials, with different letters are significantly different ($P = 0.05$).

Ruminants

Barley is commonly used in beef rations because it produces a hard white fat that is desired by consumers. Barley can be used as the sole concentrate in ruminant rations at levels up to 70% without altering performance. Zinn et al. (1996) studied the feeding value of hulled and hulless barley in a growing-finishing diet for feedlot cattle. They also evaluated different processing methods of barley on performance of cattle. Steer growth performance was not affected by the processing method or barley variety (Table 10). Steam flaked barley (SFB) appeared to have a higher average daily gain compared to the dry rolled barley (DRB). The hulless barley (HB) fed animals had a better average daily gain than the steers fed covered barley (CB). HB had a lower feed intake than CB. Steam processing of barley improved feed efficiency when compared to DRB.

Table 10. Influence of dietary treatments on growth performance of steers in a 106-day feeding trial[1]

Item	Flaked Corn	Hulless Barley		Covered Barley		SEM
		Rolled	Flaked	Rolled	Flaked	
Weight, kg[a]						
Initial	364	366	364	363	365	1
Final[b]	511	497	506	502	512	4
Weight gain, kg/d	1.41	1.25	1.33	1.33	1.38	0.05
DM intake, kg/d[c]	8.30	7.90	7.04	8.67	8.56	0.16
Intake/gain[d,e]	5.91	6.30	5.96	6.52	6.20	0.14

[1] Adapted from Zinn et al. 1996.

[a] Initial and final weights reduced 4% to account for digestive tract fill.

[b] Dry-rolled vs steam-flaked barley, $P < 0.10$.

[c] Hulless vs covered barley, $P < 0.01$.

[d] Corn vs barley, $P < 0.10$.

[e] Dry-rolled vs steam-flaked barley, $P < 0.05$.

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OAT GRAIN (*AVENA SATIVA*)

General Agronomics

Oats, a cereal grain used in the diets of livestock, are commonly grown in cooler, moister regions of western Canada. Variety, climate, and fertilization may potentially affect the chemical composition of oats (Canadian International Grains Institute 1993). Oats can successfully be grazed and used for silage, hays, and straw in ruminant rations. Western Canada produces an average of 3.3 million tonnes of oat grain annually, which is approximately 91% of total Canadian oat production (Table 1).

Table 1. Production of oats in western Canada in years 1997 to 2000

	Thousands of tonnes			
	1997	1998	1999[r]	2000[p]
British Columbia	33.5	66.3	64.8	50.6
Alberta	979.3	771.1	863.6	657.0
Saskatchewan	1403.4	1758.1	1534.5	1377.2
Manitoba	735.6	1030.2	854.4	1016.3
Canadian Total	3484.7	3957.5	3641.3	3389.4

[r] Revised

[p] Preliminary

Source: Canadian Grains Institute, Statistical Handbook 2000.

Nutrient Composition and Behavior

Oats have the lowest energy value and the highest fibre content of the cereal grains grown in western Canada (Canadian International Grains Institute 1993). This lower energy can be attributed to the fibrous hull, which typically constitutes 25 to 30% of the kernel (Morris 1990, as quoted by Mustafa et al. 1998). Oat hulls are relatively low in protein and high in fibre, which limits the amount of oats fed to non-ruminant animals, although ruminants can readily utilize these components (Mustafa et al. 1998). Hulless oats, or naked oats, have a similar energy content to that of corn (Canadian International Grains Institute 1993) or wheat (Bell and Christison 1980, as quoted by Morris and Burrows 1986). Naked oat grain and the oat groat from regular dehulled oats have a higher quality protein that provides a good source of essential amino acids (Robbins et al. 1971, as quoted by Morris and Burrows 1986). Oat starch has been shown to be more degradable than starch from corn but less rapidly degradable than wheat or barley starches (Ørskov 1986, as quoted from Mustafa et al. 1998). Tables 2 and 3 represent the nutrient composition of covered and naked oats, respectively, and Tables 4 and 5 denote the amino acid composition and characteristics and equations for predicting amino acid from crude protein content, respectively.

The cell wall content of naked oats is much lower than that of common oats; hence it has a higher energy value (Givens and Brunnen 1987). The Rowett Research Institute (1976, as quoted by Givens and Brunnen 1987) found that naked oats can have three times the lipid content than common oats. They also found that naked oats contained a higher protein content compared to common oats.

Table 2. Nutrient composition and characteristics of covered oats (100% DM basis)

Nutrient	Average Amount	SD
CP (%DM)[1]	11.75	0.49
RDP (%CP)[2]	76.55	
RUP (%CP)[2]	23.45	
ADFIP (%DM)[2]	0.68	
NDFIP (%DM)[2]	1.5	
SP (%CP)[1]	32.68	1.17
NPN (%SP)[1]	21.1	1.71
CF (%)[3]	12.1	
ADF (%)[1]	18.58	0.86
NDF (%)[1]	38.98	1.6
Lignin (%DM)[1]	7.74	0.51
Cellulose (%DM)[3]	11.0	
Starch (%DM)[1]	41.51	1.08
NSC[1]	42.55	1.4
NFC[1]	53.18	
A kd (%/hr)[2]	300.0	
B_1 kd (%/hr)[2]	35.0	
B_2 kd (%/hr)[2]	5.0	
DE (kcal/kg) (swine)[4]	3110.0	
TDN% (ruminants)[5]	78.5	
ME (kcal/kg) (poultry)[3]	2861.0	
ME (Mcal/kg) (ruminants)[5]	2.78	
NEm (Mcal/kg) (ruminants)[5]	1.90	
NEg (Mcal/kg) (ruminants)[5]	1.26	
NEl (Mcal/kg) (dairy)[5]	1.77	
Fat (EE) %[1]	5.13	0.45
Ash %[1]	2.71	0.09
Calcium %[2]	0.11	0.01
Phosphorus %[2]	0.24	0.008
Sodium %[5]	0.03	
Magnesium %[1]	0.12	0.006
Copper (mg/kg)[6]	3.97	0.28
Manganese (mg/kg)[6]	39.47	2.03
Iron (mg/kg)[6]	63.34	13.2
Zinc (mg/kg)[6]	29.43	1.72
Selenium (mg/kg)[6]	0.22	0.1

[1] Mustafa et al. 1998.

[2] NRC, Nutrient Requirements of Beef Cattle 1996.

[3] NRC, United States-Canadian Tables of Feed Composition 1982.

[4] NRC, Nutrient Requirements of Swine 1998.

[5] NRC, Nutrient Requirements of Dairy Cattle 2001.

[6] Saskatchwean Feed Test Laboratory, average of years 1974-1982, 1986, 1988, and 1990.

Table 3. Nutrient composition and characteristics of naked oats (100% DM basis)

Nutrient	Average Amount	SD
CP (%DM)[1]	14.83	0.49
RDP (%CP)[7]		
RUP (%CP)[7]		
ADFIP (%CP)[7]		
NDFIP(%CP)[7]		
SP (%CP)[1]	35.35	1.17
NPN (%SP)[1]	12.36	1.71
CF %[2]	4.50	1.26
ADF %[1]	4.35	0.86
NDF %[1]	15.36	1.6
Lignin (%DM)[2]	1.80	0.50
Cellulose (%DM)[2]	3.60	1.13
Starch (%)[1]	58.96	1.08
NSC[1]	61.02	1.4
NFC[1]	59.42	
A kd (%/hr)[7]		
B_1 kd (%/hr)[7]		
B_2 kd (%/hr)[7]		
DE (kcal/kg) (swine)[3]	4045.0	
TDN% (ruminants)[6]		
ME (kcal/kg) (poultry)[3]		
ME (kcal/kg) (swine)[3]	3965.0	
NEm (Mcal/kg) (ruminants)[6]		
NEg (Mcal/kg) (ruminants)[6]		
NEl (Mcal/kg) (dairy)[6]		
Fat (EE) %[2]	9.70	0.31
Ash %[2]	2.30	0.45
Calcium %[2]	0.07	0.013
Phosphorus %[2]	0.41	0.059
Sodium %[2]	0.02	0.004
Magnesium %[2]	0.12	0.015
Copper (mg/kg)[1]	4.10	0.53
Manganese (mg/kg)[1]	41.8	2.23
Iron (mg/kg)[1]	104.2	11.84
Zinc (mg/kg)[1]	23.3	3.78

[1] Mustafa et al. 1996.

[2] Givens and Brunnen 1987.

[3] NRC, Nutrient Requirements of Swine 1998.

Table 4. Amino acid and protein characteristics of oat grain (100% DM basis)

Amino Acid	Average Amount (%DM) [1]	Swine % Apparent Ileal Digestibility[2]	Swine % True Ileal Digestibility[2]
CP level (%)	12.92		
Arg	0.98	85	89
His	0.35	82	87
Ile	0.54	73	81
Leu	1.03	80	86
Lys	0.45	72	79
Met	0.25	76	82
Cys	0.40	70	75
Phe	0.73	81	87
Tyr	0.46	77	84
Thr	0.49	60	72
Trp	0.16	72[1]	78[1]
Val	0.74	74	82

[1] NRC, Nutrient Requirements of Swine 1998.

[2] Rhone-Poulenc Animal Nutrition 1993.

Table 5. Regression equations for predicting amino acid levels in oats from crude protein content[1]

Amino Acid	Equation	R Value
Lysine	%CP X 0.0358 + 0.0780	0.94
Methionine	%CP X 0.0182 - 0.0140	0.96
Methionine + Cystine	%CP X 0.0424 + 0.0390	0.96
Tryptophan	%CP X 0.0135 - 0.0170	0.92
Threonine	%CP X 0.0329 + 0.0210	0.98

[1] Degussa Company 1988.

USES IN LIVESTOCK AND POULTRY DIETS

Poultry

In 1993, Cave and Burrows evaluated the use of naked oats in broiler starter and grower diets (Table 6). There were three starter diets containing 0, 25, or 50% naked oats and four grower diets containing 0, 25, 50, or 75% naked oats. During the 1 to14 and 15 to 28 day periods, weight gains increased linearly in the starter diets. As the oat level increased, during the 1 to 14 day period, feed intake was reduced. The level of naked oats in the grower diet had significant effects on weight gain during the 29 to 40 day period. Weight gain increased at lower concentrations of naked oats but decreased when 75% oats were added, as compared to the control group. Female birds had a lower feed intake and weighed less than the males. Carcass weight remained the same among the starter diets, although it was lower for growers fed 75% oats than those fed a lower concentration of naked oats. As the level of oats increased in the starter diet, carcass fat seemed to decrease, however carcass fat content remained the same in the grower diets at all inclusion levels of naked oats. This study suggests that naked oats can be included in starter diets at levels up to 50% and that the optimum inclusion level in grower rations is also at 50% of the total diet.

Table 6. Effect of level of naked oats in starter and grower diets on broiler performance and carcass fat[1]

Diet	Level of Oats (%)	Weight gain (g)			Feed:gain			Carcass wt/ liveweight (%)	Abdominal fat (g)
		1-14 d	15-28 d	29-40 d	1-14 d	15-28 d	29-40 d		
Starter	0	236	641	719	1.86	1.61	2.28	68.9	17.3
	25	244	660	726	1.67	1.56	2.31	69.0	16.0
	50	246	680	710	1.65	1.54	2.39	68.9	15.1
SEM[2]		2.9	7.4	11.2	0.037	0.031	0.057	0.23	0.52
Grower	0			740			2.24	68.8	16.3
	25			749			2.35	69.1	16.1
	50			741			2.33	69.3	16.1
	75			691			2.40	68.1	16.2
SEM				13.1			0.049	0.26	0.61

[1] Adapted from Cave and Burrows, 1993.

[2] Standard error of the mean.

Swine

Galloway and Ewan (1989) evaluated the use of oat groats in starter pig rations. Increasing the level of oat groats in the diet significantly increased the average daily gain and improved the feed:gain ratio significantly (Table 7). As the level of oat groats increased, the digestibility of dry matter increased, although the nitrogen digestibility decreased. Energy digestibility remained the same among all inclusion levels. The pooled net energy value for oat groats was 2.52kcal/g, which was slightly lower than reported for corn at 2.56kcal/g (DeGoey and Ewan 1975, as quoted by Galloway and Ewan 1989). However, the net energy of oat groats were higher than reported for barley (2.11kcal/g) and wheat (2.47kcal/g) (Wu and Ewan 1979, as quoted by Galloway and Ewan 1989). This study suggests that oat groats can be used at levels up to 40% in starter pig diets, whereby the performance is improved compared to pigs consuming diets free of oat groats.

Morris and Burrows (1986) evaluated using different inclusion levels of naked oats in grower-finisher diets of pigs (Table 8). They found that weight gains did not differ amongst the oat diets and were similar compared to the control corn-soy diet. The feed intake was reduced 1.08% for every 10% increase of naked oat concentrate in the ration. It is speculated that this occurred because of the increased lipid content of oats. Pigs fed 65 and 96.75% naked oats had significantly higher carcass yield than those pigs fed 0 or 30 percent oats. The results of this study would suggest that finishing pigs can maintain similar or improved performance when fed dietary levels of up to approximately 96.7% naked oats.

Table 7. Effect of level of oat gorats on performance and digestibility of starter pigs over a 28 day period[1]

Item	Treatment[a] 1	2	3	SE
Pig Performance				
Daily gain, g[b]	124	230	347	15
Feed:gain[c]	1.7	1.4	1.3	0.03
Apparent digestibility coefficients				
Dry matter, %[d]	81.2	82.2	84.0	0.7
Nitrogen, %	90.9	89.3	88.6	0.7
Energy, %	88.6	88.0	88.6	0.8

[1] Adapted from Galloway and Ewan 1989.

[a] Treatments were 0, 25, and 40% added oat groats to the basal diet. Diets were fed at 3, 4, and 5% of BW for treatments 1, 2, and 3, respectively.

[b] Linear effect of level of oat groats ($P < 0.01$).

[c] Quadratic effect of level of oat groats ($P < 0.01$).

[d] Linear effect of level of oat groats ($P < 0.05$).

Table 8. Performance of market pigs fed diets containing naked oats form 32 to 79 kg liveweight[1]

Tibor Oats (%)	Pigs	Initial weight (kg pig^{-1})	Final weight (kg pig^{-1})	Average daily gain (kg d^{-1})	Average daily feed intake (kg d^{-1})	Feed conversion	Dressing %	Fat grading thickness (mm)	Grading index
0	32	32.4	95.8*a*	0.82*a*	2.61*a*	3.18*a*	77.4*a*	32.6*a*	104*a*
30.0	32	32.4	97.1*a*	0.84a	2.59*b*	3.09*a*	76.9*a*	32.6*a*	104*a*
65.0	32	32.5	97.1*a*	0.83*a*	2.40*bc*	2.89*b*	78.5*b*	32.2*a*	103*a*
96.75	32	32.5	97.2*a*	0.84*a*	2.36*c*	2.81*b*	78.4*b*	33.4*a*	104*a*
SEM[2]		0.14	0.75	0.01	0.04	0.04	0.27	0.93	1.08

[1] Adapted from Morris and Burrows, 1986.

[2] Standard error of the mean.

a-c Means within columns followed by the same letter are not different at ($P \leq 0.05$).

Ruminants

Oats can be used as a concentrate source in the diets of ruminant animals, although care should be given when determining inclusion levels due to the increased oil content of naked oats. Processing of oats to reduce the degradability in the rumen could be used to decrease the risk of digestive upsets. Oats can be included in ruminant rations at levels up to 50% of the total ration.

Givens and Brunnen (1987) determined the nutritive value of five different samples of naked oats for use in ruminant rations. They found that the animals did not reject the diets and digestive upsets did not occur. There was little variation in digestibility coefficients, which were high for all fractions except crude fibre. In 1999, Petit and Alary compared the dry matter, crude protein, and starch ruminal degradabilities of naked and covered oats. Covered oats had lower dry matter degradability of the readily soluble fraction than naked oats (Table 9). The potentially degradable dry matter fraction was higher for covered oats, which also had a faster dry matter disappearance rate than naked oats. The effective degradability of dry matter was higher for naked oats compared to covered oats. The crude protein ruminal degradability of the readily soluble fraction was higher for naked oats than covered oats, however the opposite occurred for the potentially degradable fraction and the crude protein disappearance rate. The effective degradability of crude protein remained the same for both types of oat. The ruminal degradability of starch, between naked and covered oats, behaved similarly to crude protein ruminal degradability (Table 9).

Table 9. Ruminal degradability of naked oats and covered oats[1]

Item[2]	Naked Oats	Oats	*P*	SE
Dry matter				
a	40.4	17.3	0.003	0.7
b	49.3	51.9	0.06	0.4
c	24.3	30.2	0.008	2.7
EDDM	77.2	58.4	0.008	0.9
Crude protein				
a	34.5	19.5	0.02	1.1
b	56.1	69.4	0.001	0.2
c	27.2	39.5	0.11	2.2
EDCP	77.7	77.7	0.8	1.3
Starch				
a	58.2	38.7	0.02	1.7
b	37.3	57.2	0.004	0.7
c	21.0	49.7	0.07	4.1
EDST	84.7	87.9	0.2	0.9

[1] Adapted from Petit and Alary 1999.

[2] a = The percentage of DM, CP, or starch solubilized at intiation of incubation; b = the percentage of DM, CP, or starch potentially degradable in the rumen; and c = the rate constant (percentage per hour) of disappearance of fraction b; EDDM = effective degradability of dry matter; EDCP = effective degradability of crude protein; EDST = effective degradability of starch, calculated at a solid outflow rate of 8%/h.

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RYE GRAIN (*SECALE CEREALE*)

General Agronomics

Rye is a cereal grain that can be utilized by all livestock. Rye is suitable to be grown in Canada because it is extremely hardy, tolerant as a fall seeded crop, and yields well in moisture limiting situations (McLeod 1992). The majority of Canadian rye is grown in the western Canadian provinces, which produced 85% of total crop over the last four years (Table 1). Fall rye may be used as forage for silages and hays, and should be cut prior to the early milk stage, to maintain optimal nutrient composition (Racz and Campbell 1995). Fall rye can also be used successfully for late fall and early spring grazing.

Table 1. Production of rye grain in western Canada for 1997 to 2000

	Thousands of tonnes			
	1997	1998	1999[r]	2000[p]
British Columbia	2.8	4.1	3.0	0.0
Alberta	66.1	77.5	72.4	42.5
Saskatchewan	138.5	152.4	168.4	97.8
Manitoba	62.2	106.7	76.2	55.9
Canadian Total	320.0	398.1	386.6	260.3

[r] Revised

[p] Preliminary

Source: Canadian Grains Institute, Statistical Handbook 2000.

Nutrient Composition and Behavior

Rye grain has a slightly higher energy level than barley, most likely attributed to the lower fibre content (3.0%), but is not as readily acceptable to livestock. The crude protein content of rye is slightly higher that of barley and oats, but lower than that of wheat (McLeod 1992). Rye contributes a high quality protein, typically higher in lysine content, as well as a reasonable amount of calcium, phosphorus, other minerals and vitamins in comparison to other cereals (McLeod 1992). Table 2 illustrates the nutrient composition and characteristics of rye and tables 3 and 4 indicate the amino acid composition and regression equations for predicting amino acids from crude protein content, respectively.

Rye should be introduced into the diet slowly so animals can become accustomed to the taste and adjust to the lower fibre content, with ruminants. Rye is susceptible to ergot contamination, a fungus inhabiting the grain, but not limited to rye alone (McLeod 1992). Ergot is usually more widespread during wet spring and early hot and humid summer seasons (Thacker 1991). Ergot, at high levels, can cause vaso-constriction of blood vessels leading to gangrenous symptoms of body extremities such as the ears or tail and may cause abortions in pregnant animals. If ergot content exceeds 0.1%, the contaminated grain may be mixed with other feed to reduce the contamination level.

Table 2. Nutrient composition and characteristics of rye grain (100% DM basis)

Nutrient	Average
CP (%DM)[1]	13.80
RDP (%CP)[1]	78.99
RUP (%CP)[1]	21.01
ADFIP (%DM)[1]	0.55
NDFIP (%DM)[1]	0.97
SP (%CP)[1]	53.00
NPN (% SP)[1]	19.00
CF %[2]	3.00
ADF %[2]	4.44
NDF %[2]	10.67
Lignin (%DM)[1]	1.00
Cellulose (%DM)[3]	3.44
Starch (%)[3]	65.12
NFC[4]	71.42
A kd (%/hr)[1]	300.0
B_1 kd (%/hr)[1]	40.0
B_2 kd (%/hr)[1]	8.0
DE (Kcal/kg) (swine)[2]	3656.0
TDN % (ruminants)[2]	85.6
ME (kcal/kg) (poultry)[3]	3001.0
ME (Mcal/kg) (beef)[1,5]	3.04
NEm (Mcal/kg) (beef)[1,5]	2.06
NEg (Mcal/kg) (beef)[1,5]	1.40
NEl (Mcal/kg) (dairy)[5]	1.94
Fat (EE) %[2]	1.89
Ash %[2]	2.22
Calcium %[2]	0.07
Phosphorus %[2]	0.42
Sodium %[6]	0.02
Magnesium %[6]	0.14
Copper (mg/kg)[2]	6.00
Manganese (mg/kg)[2]	38.00
Iron (mg/kg)[6]	68.18
Zinc (mg/kg)[2]	28.00
Selenium (mg/kg)[6]	0.43

[1] NRC, Nutrient Requirements of Beef Cattle 1996.

[2] Racz and Campbell 1995.

[3] McLeod 1992.

[4] NFC Equations, NRC, Nutrient Requirements of Dairy Cattle 2001.

[5] Energy Equations, NRC, Nutrient Requirements of Dairy Cattle 2001.

[6] NRC, Nutrient Requirements of Swine 1998.

Rye grain contains non-starch polysaccharides (NSP), namely pentosans, which are highly soluble and will readily go into solution, increasing viscosity in the gut of non-ruminants not capable of breaking down pentosans. This may impair the utilization of rye, particularly in poultry. Enzyme supplementation of pentosanase in the diet of rye fed poultry has been shown to reduce the levels of NSP in rye allowing poultry to better utilize rye. Currently, breeders of rye grain are developing low viscosity varieties of rye that are better utilized by poultry.

Table 3. Amino acid and protein characteristics of rye grain (100% dry matter basis)

Amino Acid	Average Amount (%DM)[1]	Swine % Apparent Ileal Digestibility[1]	Swine % True Ileal Digestibilty[1]	Poultry % True Ileal Digestibiliy[2]
CP level (%)	13.41			
Arg	0.57	73	79	82
His	0.27	71	78	73
Ile	0.42	68	77	76
Leu	0.73	71	79	81
Lys	0.43	64	73	75
Met	0.19	76	81	77
Cys	0.22	74	83	73
Phe	0.57	76	82	82
Tyr	0.30	65	76	77
Thr	0.36	59	73	78
Trp	0.14	67	75	56
Val	0.58	67	75	81

[1] NRC, Nurtient Requirements of Swine 1998.
[2] Rhone-Poulenc Animal Nutrition 1993.

Table 4. Regression equations for predicting amino acid levels in rye from crude protein content[1]

Amino Acid	Equation	R Value
Lysine	%CP X 0.0179 + 0.2170	0.40
Methionine	%CP X 0.0194 - 0.0130	0.76
Methionine + Cystine	%CP X 0.0460 - 0.0240	0.77
Tryptophan	%CP X 0.0054 + 0.0420	0.61
Threonine	%CP X 0.0281 + 0.0740	0.67

[1] Degussa Corporation 1988.

USE IN LIVESTOCK AND POULTRY DIETS

Poultry

When feeding rye in poultry diets, enzyme supplementation is necessary, because poultry do not have the naturally occurring enzymes to digest pentosans (McLeod 1992). Rye grain is not recommended for growing broilers and turkeys due to its high level of soluble fibre, which affects growth and litter quality. Rye can be fed to laying hens, but it should be introduced gradually after hens have reached peak performance. Research has shown that egg production was not affected, provided that rye did not exceed 40% of the diet. Feed conversion with rye is typically better than barley based diets alone, and/or 50:50 barley wheat diets (Racz and Campbell 1995).

Swine

Rye can constitute up to 50% of the diet for grower finisher pigs, 40% for lactating sows, and the whole grain portion of the diet for dry sows on feed restriction. It is recommended that pigs less than 25 kg should not be fed rye because of acceptability problems (Racz and Campbell 1995). Enzyme supplementation can be used in swine diets, but it does not have a significant effect on performance (Table 5).

Table 5. Effect of enzyme supplementation on the performance of pigs fed rye grain[1]

	Control	Rye	Rye and Enzyme
Average Daily Gain (kg)	0.80	0.76	0.78
Average Daily Feed (kg)	2.19	2.02	2.06
Feed:gain	2.74	2.66	2.64

[1] Adapted from Thacker et al. 1987.

Ruminants

Rye can be included at 10 to 30% in finishing rations of feedlot cattle, up to 35 to 40% of the diet for backgrounded calves, and 25% of the concentrate mix for dairy cattle (Racz and Campbell 1995). Table 6 illustrates the similar performance of rye compared to barley grain using barley silage as the base forage. Steers fed 100% rye grain gained the most weight and had the best feed conversion compared to 100% barley rations and barely/rye combined diets. Rye is not recommended for creep feeds and starter calves because of palatability problems (Racz and Campbell 1995).

Table 6. Performance of finishing steers (72-100 days) fed levels of rye grain

	Barley 100%	Barley 40% Rye 60%	Rye 100%
Average Daily Gain (kg)	1.26	1.23	1.31
Feed/Gain	7.39	7.14	6.85

Source: T. Devlin, as quoted by Racz and Campbell 1995.

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TRITICALE GRAIN

General Agronomics

Triticale is a man-made hybrid of wheat and rye. It is designed to combine the environmental tolerance and disease resistance of rye with the feeding quality approaching wheat (Goonewardene et al. 1994). Triticale can also be successfully grazed and used as silage in ruminant diets. ZoBell et al. (1992) found that triticale silage was comparable to barley silage, with respect to average daily gain, when added at 25% of the diet. Saskatchewan triticale production was estimated at 31,800 tonnes for 2000, which was down 24% from 1999 production of 41,900 tonnes (Saskatchewan Agriculture and Food 2000).

Nutrient Composition and Behavior

The literature is indefinite when dealing with comparison of triticale to other grain sources. Some show that they are similar and can be substituted for some or all of the grain portion of the diets (Kochetova et al. 1987, ZoBell et a. 1990, as quoted by Goonewardene 1994) and others say that lower performance was noted with other cereal grains, for instance corn (Jordan and Hanke 1972, as quoted by Goonewardene 1994) or wheat (Reddy et al. 1975, as quoted by Goonewardene 1994. This variation is likely due to sample differences and its actual nutrient composition. The selection for higher starch content has resulted in a slightly lower protein and amino acid content than earlier varieties. The digestible energy content of some triticale varieties is similar but slightly lower than that of corn (Myer 1989, as quoted by Jaikaran et al. 1998). In contrast, these new varieties have a substantially higher protein content than corn and are comparable to wheat. Triticale is higher in lysine than wheat, but protein and amino acid supplementation is still needed to meet the requirements of growing finishing pigs (Myer et al. 1996, as quoted by Jaikaran et al. 1998). Table one represents the nutrient composition and characteristics of triticale and tables two and three indicate the amino acid characteristics and regression equations to predict amino acid contents from protein levels, respectively.

As with rye, ergot contamination should be monitored and it should not be added in the diet greater than 35% because of palatability problems (Racz 1996). Triticale may contain anti-nutritional factors, which can lead to decreased utilization in non-ruminants but have little or no effect on ruminant utilization (Goonewardene et al. 1994).

Table 1. Nutrient composition and characteristics of triticale grain (100% DM basis)

Nutrient	Average
CP (%DM)[1]	17.60
RDP (%CP)[?]	
RUP (%CP)[?]	
ADFIP (%DM)[?]	
NDFIP (%DM)[?]	
SP (%CP)[?]	
NPN (% SP)[?]	
CF %[1]	4.40
ADF %[2]	4.22
NDF %[2]	14.11
Lignin (%DM)[?]	
Cellulose (%DM)[?]	
Starch (%)[?]	
NFC[3]	64.59
A kd (%/hr)[?]	
B_1 kd (%/hr)[?]	
B_2 kd (%/hr)[?]	
DE (kcal/kg) (swine)[1]	3673.0
TDN % (ruminants)[1]	84.0
ME (kcal/kg) (poultry)[1]	3521.0
ME (kcal/kg) (swine)[2]	3533.0
NEm (Mcal/kg) (beef)[1]	2.00
NEg (Mcal/kg) (beef)[1]	1.35
NEl (Mcal/kg) (dairy)[1]	1.94
Fat (EE) %[1]	1.70
Ash %[1]	2.00
Calcium %[1]	0.06
Phosphorus % [1]	0.33
Sodium %[2]	0.03
Magnesium %[2]	0.11
Copper (mg/kg)[2]	8.89
Manganese (mg/kg)[2]	47.78
Iron (mg/kg)[2]	34.44
Zinc (mg/kg)[2]	35.56

[1] NRC, United States-Canadian Tables of Feed Composition 1982.

[2] NRC, Nutrient Requirement of Swine 1998.

[3] NFC Equations, NRC, Nutrient Requirements of Dairy Cattle 2001.

Table 2. Amino acid and protein characteristics of triticale grain (100% dry matter basis)

Amino Acid	Average Amount[1]	Swine % Apparent Ileal Digestibility[1]	Swine % True Ileal Digestibilty[1]	Poultry % True Ileal Digestibiliy[2]
CP level	13.89			
Arg	0.63	85	88	90
His	0.29	84	84	90
Ile	0.43	80	84	88
Leu	0.84	82	86	88
Lys	0.43	76	81	84
Met	0.22	85	89	89
Cys	0.29	83	87	82
Phe	0.54	84	85	90
Tyr	0.36	81	83	90
Thr	0.4	69	76	85
Trp	0.16	74	88	
Val	0.57	79	84	90

[1] NRC, Nutrient Requirements of Swine 1988.

[2] Rhone-Poulenc Animal Nutrition 1993.

Table 3. Regression equations for predicting amino acid levels in triticale from crude protein content[1]

Amino Acid	Equation	R Value
Lysine	%CP X 0.0183 + 0.2050	0.61
Methionine	%CP X 0.0131 + 0.0550	0.78
Methionine + Cystine	%CP X 0.0309 + 0.1310	0.75
Tryptophan	%CP X 0.0081 + 0.0260	0.83
Threonine	%CP X 0.0214 + 0.1390	0.71

[1] Degussa Corporation 1988.

USES IN LIVESTOCK AND POULTRY DIETS

Poultry

Triticale is growing in popularity as a feed ingredient in poultry rations. In 1995, Vieira et al. measured the effects of different inclusion levels of triticale on male broiler performance. Table 4 indicates the results of this experiment and shows that broiler performance remained the same at all inclusion levels of triticale. From this a conclusion can be made that triticale can be used in the diets of broilers up to 40% without having any negative implications on chick performance.

Table 4. Influence of triticale on performance of male broilers[1]

% of Triticale	1-21 DAYS			21-42 DAYS			1-42 DAYS		
	Feed Intake	Feed Conversion	Body Weight Gain	Feed Intake	Feed Conversion	Body Weight Gain	Feed Intake	Feed Conversion	Body Weight Gain
	g	g/g	g	g	g/g	g	g	g/g	g
0	1100	1.51	728	2836	1.93	1473	3921	1.80	2180
10	1105	1.53	721	2744	1.93	1422	3828	1.78	2156
20	1073	1.55	692	2744	1.90	1458	3854	1.78	2172
30	1120	1.50	746	2902	2.03	1432	4016	1.83	2202
40	1099	1.53	721	2933	1.99	1422	3998	1.81	2197
Mean	1099	1.52	722	2838	1.95	1441	3923	1.80	2181
SEM	56	0.06	40	108	0.08	48	128	0.04	65

[1] Adapted from Vieira et al. 1995.

Swine

Triticale can be used effectively in swine diets. Jaikaran et al. (1998) compared triticale, corn, and hulless barley based diets against one another. The effects of these diets on pig performance are shown in Table 5. Throughout the experiment, there were no significant differences in feed intake among treatment groups, however barrows had a significantly higher intake than gilts. Consequently, barrows had a higher average daily gain than did gilts. Feed efficiencies did not differ among treatments and was similar between sexes. The similar feed intakes, average daily gains, and feed efficiencies exhibited throughout this experiment would suggest than corn, hulless barley, and triticale are similar in nutritional value and can be substituted for one another (Jaikaran et al. 1998).

Table 5. Average daily feed intake, average daily gain and feed efficiency of pigs fed diets of corn, hulless barley, triticale and a 1:1 mixture of hulless barley and triticale in their diet

	Average Daily Feed Intake (kg)				Average Daily Gain (g)				Feed Efficiency (f:g)			
Treatment	27-50 kg	50-84 kg	84-101 kg	27-110 kg	27-50 kg	50-84 kg	84-101 kg	27-110 kg	27-50 kg	50-84 kg	84-101 kg	27-110 kg
By Treatment												
Corn	2.00	2.53	2.85	2.50	923	927	821b	885	2.17	2.73	3.47	2.85
Hulless barley	1.95	2.59	3.06	2.53	918	924	921a	915	2.20	2.81	3.42	2.87
Triticale	2.05	2.60	2.85	2.50	924	972	881ab	899	2.22	2.67	3.25	2.81
Hulless barley and triticale	2.10	2.67	2.97	2.66	926	995	864ab	935	2.66	2.68	3.44	2.86
SEM	0.09	0.09	0.06	0.08	26	26	35	23	0.09	0.07	0.10	0.04
By Sex												
Barrows	2.11a	2.70a	3.16a	2.65a	940	1006a	934a	949a	2.29	2.71	3.42	2.86
Gilts	1.93b	2.49b	2.70b	2.45b	905	910b	806b	867b	2.14	2.74	3.37	2.84
SEM	0.06	0.07	0.05	0.06	19	18	35	23	0.06	0.05	0.07	0.03

[1] Adapted from Jaikaran et al. 1998.

a,b Values with different letters in the columns are significantly different (P<0.05).

Ruminants

In 1994, Goonewardene et al. compared the performance of steers fed barley and triticale diets (Table 6). The overall average daily gain of steers fed triticale tended to be lower than the barley fed steers, although the feed:gain ratios were similar of both grains. Adaptation of the diets played a big role in performance, as the steers adapted more readily to the barley based diets than the triticale diets. The feed intake of triticale diets was 9.5% lower than the barley based diet, which may have attributed to the reduced average daily gain of triticale fed steers. McQueen and Fillmore (1991) found that triticale based diets were readily accepted by dairy cattle with similar milk yields and composition as barley fed dairy cattle.

Table 6. Least square means for average daily gain, feed intake and feed:gain ratio of steers fed barley and triticale over 102 days[1]

Performance	Barley	Triticale	SEM[2]	*P*
Average Daily Gain (kg)	1.5	1.3	0.07	0.08
Feed:Gain ratio	6.8	7.1	0.30	0.65
Feed Intake (kg)				
Day 0-18	9.3	7.3	0.30	0.03
Day 19-49	10.9	10.4	0.40	0.44
Day 50-89	10.8	9.8	0.40	0.23
Day 90-102	10.5	9.8	0.40	0.22
Day 0-102	10.5	9.7	0.30	0.08

[1] Goonewardene et al. 1994.

[2] Pooled standard error of the mean.

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WHEAT GRAIN (*TRITICUM AESTIVUM*)

General Agronomics

Wheat, a cereal grain, is used in the diets of all classes of livestock. Canada produces an average of 23.5 million tonnes annually, with approximately 93% of that grown in Western Canada (Table 1). There are several classes of wheat grown in the prairies, which may differ in nutrient composition with changing types, varieties, and growing conditions (Canadian International Grains Institute 1993; Alberta Agriculture 1997; Shellenberger 1978). Winter wheat usually yields about 10 to 15% higher than spring types and is used mainly for baking purposes (Alberta Agriculture 1997). Hard red spring wheat is known for its earlier maturing varieties that are best suited for brown, dark brown, and black soil zones and is used mainly for bread making (Alberta Agriculture 1997). Durum wheat is typically produced for pasta making, although it is increasing in popularity among the poultry industry as a feed wheat, because of its distinctive characteristics (Scott et al. 1998). All Canadian durum wheat is produced in the Western provinces (Table 2). Soft white spring wheat is higher yielding but has a lower protein content than other types of wheat. This class of wheat is commonly used in the livestock feed industry (Alberta Agriculture 1997).

Table 1. Production of Wheat, Except Durum, in Western Canada for years 1997 to 2000

	Thousands of tonnes			
	1997	1998	1999[r]	2000[p]
British Columbia	62.1	76.5	97.5	93.9
Alberta	6104.5	5609.2	7321.1	6539.4
Saskatchewan	9559.5	7892.4	10432.1	8775.3
Manitoba	3244.1	3029.2	3122.9	4124.5
Canadian total	19928.6	18034.4	22599.9	21156.9

[r] Revised

[p] Preliminary

Source: Canadian Grains Institute, Statistical Handbook 2000.

Table 2. Production of Durum Wheat in Western Canada for years 1997 to 2000

	Thousands of tonnes			
	1997	1998	1999[r]	2000[p]
Alberta	734.8	1143.1	857.3	748.4
Saskatchewan	3510.8	4708.3	3407.4	4757.3
Manitoba	106.1	190.5	35.4	141.5
Canadian total	4351.7	6041.9	4300.1	5647.2

[r] Revised

[p] Preliminary

Source: Canadian Grains Institute, Statistical Handbook 2000.

Nutrient Composition and Behavior

Wheat is valued for its higher energy and its high protein content. Bhatty et al. 1974 (as quoted by Bedford et al. 1998) found crude protein levels of 17 different varieties of wheat ranged from 13 to 19%. Bedford et al. (1998) evaluated several varieties of hard red spring (HRS), Canadian prairie spring (CPS), and durum wheat and found that HRS wheat had the highest crude protein followed by durum then CPS wheat. Although the protein content of wheat can vary greatly, on average it is the cereal most abundant in protein (Shellenberger 1978). The energy content of wheat is slightly lower than that of corn but higher than barley or oats. Wheat has similar mineral and fat contents when compared with other cereals (Shellenberger 1978).

Wheats contain a non-starch polysaccharide (NSP) called pentosans. High levels of NSP in the diet may produce wet litter, sticky droppings, and reduced performance in young broilers (Classen et al. 1988, as quoted by Scott et al. 1998). These NSP can be reduced or eliminated through the use of enzymes, namely pentosanase.

Table 3. Amino acid and protein characteristics of wheat (100% DM basis)

Amino Acid	Average Amount (%DM)[1]	Swine % Apparent Ileal Digestibility[2]	Swine % True Ileal Digestibilty[2]	Poultry % True Ileal Digestibily[2]
CP level (%)	16.02			
Arg	0.76	81	87	85
His	0.37	83	89	88
Ile	0.53	82	88	89
Leu	1.06	84	89	90
Lys	0.43	70	80	83
Met	0.26	85	89	89
Cys	0.34	83	89	88
Phe	0.76	85	90	90
Tyr	0.45	81	88	89
Thr	0.47	70	84	82
Trp	0.18	82	90	93
Val	0.69	79	86	87

[1] NRC, Nutrient Requirements of Swine 1998, Hard Red Spring Wheat.

[2] Rhone-Poulenc Animal Nutrition 1993.

Table 4. Amino acid composition of durum wheat (100% DM basis)

Amino Acid	Average Amount (% DM)[1]	Average Amount (%DM)[2]	SEM[3]
CP level (%)	15.90	16.11	
Arg	0.68	0.65	0.11
His	0.32	0.35	0.07
Ile	0.57	0.53	0.11
Leu	1.54	1.03	0.22
Lys	0.41	0.36	0.09
Met	0.17	0.24	0.04
Cys	0.15	0.31	0.05
Phe	0.66	0.72	0.17
Tyr	0.36	0.48	0.12
Thr	0.43	0.41	0.08
Trp	0.30	0.15	0.08
Val	0.65	0.62	0.12

[1] NRC, United States-Canadian Tables of Feed Composition 1982.

[2] Bedford et al. 1998.

[3] Standard error of the mean.

Table 5. Regression equations for predicting amino acid levels in wheat from crude protein content[1]

Amino Acid	Equation	R Value
Lysine	%CP X 0.0289 - 0.0090	0.76
Methionine	%CP X 0.0159 + 0.0010	0.92
Methionine + Cystine	%CP X 0.0324 + 0.0720	0.93
Tryptophan	%CP X 0.0091 + 0.0310	0.85
Threonine	%CP X 0.0281 + 0.0100	0.93

[1] Degussa Corporation 1998.

Table 6. Nutrient composition and characteristics of hard red spring wheat (100% DM basis)

Nutrient	Average	SD
CP (%DM)[1]	16.14	2.0
RDP (%CP)[2]	73.95	
RUP (%CP)[2]	26.05	
ADFIP (%DM)[2]	0.28	0.1
NDFIP(%DM)[2]	0.57	0.7
SP (%CP)[2]	30.0	
NPN (%SP)[2]	73.0	
CF %[3]	2.90	
ADF %[4]	4.40	3.6
NDF %[4]	13.4	6.2
Lignin (%DM)[2]	0.73	
Cellulose (%DM)[3]	8.00	
Starch (%)[2]		
NFC[5]	66.16	
A kd (%/hr)[2]	300.0	
B_1 kd (%/hr)[2]	40.0	
B_2 kd (%/hr)[2]	8.0	
DE (kcal/kg) (swine)[6]	3864.0	
TDN% (ruminants)[2]	84.0	
ME (kcal/kg) (poultry)[3]	3194.0	
ME (kcal/kg) (swine)[6]	3693.0	
NEm (Mcal/kg) (ruminants)[3]	2.15	
NEg (Mcal/kg) (ruminants)[3]	1.47	
NEl (Mcal/kg) (dairy)[3]	2.06	
Fat (EE) %[4]	2.30	1.1
Ash %[4]	2.00	0.3
Calcium %[1]	0.07	0.02
Phosphorus %[1]	0.38	0.03
Sodium %[2]	0.02	
Magnesium %[1]	0.17	0.04
Copper (mg/kg)[1]	8.58	0.02
Manganese (mg/kg)[1]	38.01	7.04
Iron (mg/kg)[1]	88.84	52.00
Zinc (mg/kg)[1]	31.09	10.12
Selenium (mg/kg)[2]	0.34	

[1] Saskatchwean Feed Test Laboratory, average of years 1974-1982, 1986, 1988, and 1990.

[2] NRC, Nutrient Requirements of Beef Cattle 1996.

[3] NRC, United States-Canadian Tables of Feed Composition 1982.

[4] NRC, Nutrient Requirements of Dairy Cattle 2001.

[5] NFC Equations, NRC, Nutrient Requirements of Dairy Cattle 2001.

[6] NRC, Nutrient Requirements of Swine 1998.

Table 7. Nutrient composition and characteristics of durum wheat (100% DM basis)[1]

Nutrient	Average Amount
CP (%DM)	15.90
RDP (%CP)	
RUP (%CP)	
ADFIP (%DM)	
NDFIP (%DM)	
SP (%CP)	
NPN (%SP)	
CF %	2.50
ADF %	
NDF %	
Lignin (%DM)	
Cellulose (%DM)	
Starch (%)	
NFC	
A kd (%/hr)	
B_1 kd (%/hr)	
B_2 kd (%/hr)	
DE (Kcal/kg) (swine)	3763.0
TDN% (ruminants)	85.0
ME (Kcal/kg) (poultry)	3652.0
ME (Kcal/kg) (swine)	3492.0
NEm (Mcal/kg) (ruminants)	2.03
NEg (Mcal/kg) (ruminants)	1.37
NEl (Mcal/kg) (dairy)	1.96
Fat (EE) %	2.00
Ash %	1.80
Calcium %	0.10
Phosphorus %	0.41
Sodium %	
Magnesium %	0.17
Copper (mg/kg)	8.00
Manganese (mg/kg)	32.00
Iron (mg/kg)	48.00
Zinc (mg/kg)	37.00
Selenium (mg/kg)	1.02

[1] Adapted from NRC, United States-Canadian Tables of Feed Composition 1982.

USES IN LIVESTOCK AND POULTRY DIETS

Poultry

Wheat usually constitutes the main grain portion of poultry diets. Enzyme supplementation for poultry is common in wheat based diets, because of the higher level of NSP. Scott et al. (1998) studied the effects of different cultivars of wheat on broiler chick performance, with and without enzyme supplementation. Chicks fed hard red spring (HRS) wheat did the poorest with respect to chick performance, having decreased feed intake, decreased weight gain, and an increased feed:gain ratio compared to Canadian prairie spring (CPS) or durum wheat fed to broilers (Table 8). It was found that durum wheat cultivars had higher AME and decreased digesta viscosity than HRS or CPS wheat fed chickens, with or without enzyme supplementation. However, the durum wheat samples had a low response to the enzymes. This, along with the low digesta viscosity, indicates that durum wheat may be lower in NSP content. The commonly fed CPS wheat had the opposite reaction, with the lowers AME and the highest response to enzymes, suggesting that it may be high in NSP, reducing its value as a feedstuff. The HRS wheat also produced relatively high digesta viscosity and had low performance values.

Table 8. Performance of chicks fed eight cultivars of wheat in diets with and without enzyme supplementation[z]

	17 d body weight		Feed:gain 4-17 d (g:g)		Feed intake (g bird^{-1} d^{-1})	
Cultivar	E-[y]	E+	E-	E+	E-	E+
Biggar (CPS)	354*cd*	375*bc*	1.66*ab*	1.54*a*	33.2*ab*	34.1*ab*
Genesis (CPS)	341*de*	378*abc*	1.68*a*	1.52*ab*	32.4*bcd*	34.4*a*
Kyle (DUR)	362*bc*	385*ab*	1.50*e*	1.45*e*	31.8*cd*	33.5*bc*
Plenty (DUR)	373*ab*	374*bc*	1.48*e*	1.47*de*	32.7*bcd*	32.7*c*
Sceptre (DUR)	378*a*	389*a*	1.57*cd*	1.49*bcd*	34.3*a*	34.2*a*
CDC Teal (HRS)	346*de*	370*c*	1.61*bc*	1.53*ab*	31.6*de*	32.9*bc*
Katepawa (HRS)	334*ef*	355*d*	1.61*c*	1.51*bc*	30.4*e*	31.3*d*
Laura (HRS)	323*f*	373*bc*	1.70*a*	1.52*ab*	30.5*e*	33.6*abc*
SEM	5	5	0.02	0.01	0.5	0.4

[z] Adapted from Scott et al. 1998.

[y] E- signifies values for observations form dites without supplemental enzymes and E+ signifies values for observations from diets with supplemental enzyme.

a-f Means within followed by no common letters are significantly different at $P < 0.05$.

Swine

Mitchall et al. (1976) compared nutrient digestibility and performance of pigs fed wheat, barley, and hulless barley. Wheat tended to have slightly lower daily gains, decreased feed intake, and poorer feed efficiencies compared to covered and hulless barley, although it was not significant (Table 9). Dry matter and protein digestibilities were significantly higher for wheat compared to either barley type. Energy digestibility remained the same among all rations (Table 10). This data implies that wheat is similar in feeding value to hulless barley.

Table 9. Growth and feed utilization of pigs from 22 to 55 kg[1]

Treatment	Daily gain (kg)	Daily feed (kg)	Feed/gain ratio
CB A[2]	0.65	1.58	2.41
CB B	0.67	1.60	2.41
HB A	0.60	1.46	2.44
HB B	0.59	1.45	2.47
Wheat	0.59	1.47	2.50

[1] Adapted from Mitchall et al. 1976.

[2] CB denotes covered barley and HB denotes hulless barley; A and B denote different barley varieties.

Table 10. Digestibility coefficients for dry matter, crude protein, and energy in diets[1]

	Apparent Digestibility (%)		
Treatment	Dry Matter	Protein	Energy
CB-A[2]	74.4*bc*[3]	74.7*b*	74.3
CB-B	73.3*c*	71.6*b*	72.1
HB-A	80.4*ab*	70.7*b*	78.4
HB-B	78.8*bc*	68.6*b*	76.2
Wheat	80.4*ab*	81.4*a*	79.2

[1] Adapted from Mitchall et al. 1976.

[2] CB denotes covered barley and HB denotes hulless barley.

[3] Means for each diet component, within trials, bearing similar letters do not differ significantly ($P = 0.05$).

Ruminants

Wheat can comprise up to 60% of the total diets for ruminants. Traditionally wheat is not used in ruminant diets because of its digestive properties within the rumen. Wheat starch is rapidly degraded in the rumen and it is low in fibre content (see ADF). When using wheat as the main concentrate in ruminant diets, careful consideration should be taken to formulate rations, so as not to cause digestive upsets.

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OILSEEDS AND OILSEED MEALS

CANOLA MEAL

General Description

Canola meal is the product resulting from the crushing and oil extraction of the canola seed. It is essentially rapeseed meal that contains less than 2 percent erucic acid in the oil and less than 30μM/g of alkenyl glucosinolates per gram of oil-free dry matter of the seed (Bell 1993a). Advances in breeding of these low erucic acid and glucosinolate lines led to the adoption of a new name, canola, for the crop to differentiate it from rapeseed. Canola meal has low levels of oil and the concern of glucosinolates has been greatly reduced, although selective plant breeding has reduced these compounds to near zero (Canadian International Grains Institute 1993). Variation in chemical composition of canola meal can result from differences in variety, species, processing conditions, soil or region, and environmental conditions (Bell 1995). Canola meal in western Canada is used in pig and poultry diets and is the main protein source in dairy rations. Canola production in western Canada from 1997 to 2000 is illustrated in Table 1, whereby approximately 99% of all Canadian canola is produced in the western provinces.

Table 1. Production of canola in western Canada for years 1997 to 2000

	Thousands of tonnes			
	1997	1998	1999[r]	2000[p]
British Columbia	22.7	61.2	62.4	55.2
Alberta	2109.2	2472.1	2971.0	2154.6
Saskatchewan	2698.9	3231.8	3975.7	3379.3
Manitoba	1496.9	1803.0	1707.8	1487.8
Canadian Total	6393.1	7643.3	8798.3	7118.7

[r] Revised

[p] Preliminary

Source: Canadian Grains Institute, Statistical Handbook 2000.

Nutrient Composition and Behavior

Canola meal is valued as a protein source and contains 36 to 44% crude protein, typically about 38 to 40% on a dry matter basis (Bell 1995). Canola meal has a higher crude protein content than sunflower meal or linseed meal but lower than soybean meal or cottonseed meal (Dairy NRC 2001). Canola meal is relatively high in sulfur containing amino acids, which allows canola meal to complement feedstuffs lacking in these amino acids, such as field peas (Bell 1993b; Racz 1997). Canola meal is also rich in threonine, however the lysine content of canola meal is lower than that of soybean meal (Bell 1995). Table 2 represents the amino acid and protein characteristics of canola

meal and Table 3 illustrates regression coefficients for predicting amino acids from crude protein levels in rapeseed meal. The energy of canola meal differs with varying oil and protein contents, whereby samples that contain more oil and protein have a higher energy content (Bell 1993b). The average AME for growing and adult poultry is about 1900 to 2000 kcal/kg and the DE for swine averages about 3000 kcal/kg (Bell 1993b). The hull of canola meal represents approximately 16% of the seed weight and 30% of the meal and contributes fibre to the meal (Bell 1995). Removal of the hull has been seen to improve the nutritional value of the meal, however the hull contains protein and its removal may alter the amino acid characteristics of the meal (Bell 1995). The ether extract of canola meal tends to be relatively high, as with most oilseeds, due to the inclusion of canola gums, which are obtained from canola refining and added back to the meal to increase the energy content (Bell 1993b). Canola meal is a good source of minerals compared to other oilseed meals (Bell 1993b). Table 4 illustrates the nutrient composition and characteristics of canola meal.

Table 2. Amino acid and protein characteristics of canola meal (100% dry matter basis)

Amino Acid	Average Amount (%DM)[1]	Swine % Apparent Ileal Digestibility[2]	Swine % True Ileal Digestibility[2]	Poultry % True Ileal Digestibility[2]
CP level	37.8			
Arg	2.65	84	87	93
His	1.06	82	85	86
Ile	1.45	75	78	86
Leu	2.56	79	82	90
Lys	2.12	75	78	80
Met	0.71	84	86	91
Cys	0.96	81	84	82
Phe	1.53	78	83	90
Tyr		75	80	86
Thr	1.67	71	76	82
Trp	0.55	76	80	89
Val	1.79	72	76	80

[1] NRC, Nurtient Requirements of Dairy Cattle 2001.

[2] Rhone-Poulenc Animal Nutrition 1993.

Table 3. Regression equations for predicting amino acid levels in rapeseed meal from crude protein content[1]

Amino Acid	Equation	R Value
Lysine	%CP X 0.0702 - 0.2250	0.81
Methionine	%CP X 0.0136 + 0.2240	0.59
Methionine + Cystine	%CP X 0.0489 - 0.1150	0.72
Tryptophan	%CP X 0.0198 - 0.2310	0.74
Threonine	%CP X 0.0368 + 0.1530	0.91

[1] Degussa Company 1988.

USE IN LIVESTOCK AND POULTRY DIETS

Poultry

Leeson et al. (1987) conducted a study evaluating broiler and layer performance when fed different inclusion levels of canola meal substituted for soybean meal. Table 5 shows the results of the broiler trial, whereby no differences in feed intake, feed efficiency, and weight gain were found when the dietary level of canola meal increased. Similarly, Table 6 illustrates that the inclusion level of canola meal did not affect layer performance or egg shell quality. Leeson et al. (1987) concluded that canola meal could replace soybean meal, in part or whole, in broiler and layer rations, without causing detrimental effects on bird performance.

Table 5. Effects of substition of canola meal (CM) for soybean meal (SBM) on performance of broilers (0 to 3 weeks)[1]

	100% SBM	75% SBM 25% CM	50% SBM 50%CM	25% SBM 75% CM	100% CM	SEM	Significance
Daily feed intake (g/bird)	40.4	41.4	39.3	40.3	38.5	2.0	NS
Body weight gain (0-3 wks) (g/bird)	517.2	517.2	520.0	505.8	506.5	37.0	NS
Feed:gain	1.64	1.67	1.59	1.68	1.60	0.09	NS

[1] Adapted from Leeson et al. 1987.

Table 6. Effects of substition of canola meal (CM) for soybean meal (SBM) on performance of laying hens[1]

	100% SBM	75% SBM 25% CM	50% SBM 50%CM	100% CM	SEM	Significance
Feed intake (g/hen/d)	104.2	101.0	105.8	100.7	15.0	NS
Weight gain[y] (g/bird)	-6.9	17.5	24.4	54.4	52.2	NS
Egg production (HDB[z], %)	91.6	83.6	89.0	89.0	11.4	NS
Egg weight (g)	55.7	55.8	55.3	56.1	31.1	NS
Egg shell deformation (µm)	25.2	23.7	23.9	25.3	3.0	NS

[1] Adapted from Leeson et al. 1987.

[y] Weight gain is averaged over 8 weeks.

[z] HDB = hen-day basis.

Canola meal is usually limited to 10% of the layer diet because of increased layer mortality at higher levels (Hickling 1993). Studies have shown that canola meal does not have an effect on the number of eggs produced (Kiiskinen 1989, as quoted by Hickling 1993).

Swine

The use of canola meal in starter swine rations should be limited, as performance tends to become poorer as the inclusion level increases (Pierce 1993). It has been found that for every 1% inclusion of canola meal in the starter diet, there is a 0.6% decrease in feed intake and a 0.5% reduction in daily gain (Baidoo et al. 1987, as quoted by Pierce 1993). Canola meal can be used up to 75% of the total supplemental protein source in growing rations (Pierce 1993). Pierce (1993) evaluated a study conducted by Baidoo et al. (1987) where different dietary levels of canola meal were fed to growing and finishing pigs. No differences were found in feed intake or feed:gain ratio of growing pigs, however a significant reduction occurred in daily gain when canola meal was included at levels higher than 75 percent of the supplemental protein (Table 7).

Although canola meal should be limited to less than 25% of the supplemental protein in starter rations, it is a desirable protein source for growing, finishing, and breeding swine. Canola meal can be used at 50 to 75% of the supplemental protein source in growing rations and as the sole supplemental protein source for finishing and breeding swine (Pierce 1993).

Table 7. Average performance of growing pigs (20-60 kg) and finishing pigs (60-90 kg) fed diets supplemented with soybean meal (SBM) and canola meal (CM)[1]

	100% SBM	75% SBM 25% CM	50% SBM 50% CM	25% SBM 75% CM	100% CM
Performance (growing pigs)					
Average daily intake, kg	1.86	1.83	1.80	1.79	1.79
Average daily gain, kg	0.78	0.74	0.74	0.71	0.69
Feed:gain ratio	2.40	2.58	2.47	2.51	2.61
Performance (finishing pigs)					
Average daily intake, kg	2.73	2.72	2.72	2.69	2.69
Average daily gain, kg	0.90	0.91	0.88	0.85	0.83
Feed:gain ratio	3.03	2.99	3.09	3.16	3.24

[1] Adapted from Baidoo et al. 1987, as quoted from Pierce 1993.

Ruminants

Mustafa et al. (1996) compared the nutrient and chemical properties of high and low fibre canola meals. Tail-end dehulling is a process that could be used to alter the distribution of fibre components between two fractions, ultimately resulting in a high fibre canola meal (HFCM) and a low fibre canola meal (LFCM). Mustafa et al. (1997) studied the effects of feeding HFCM relative to regular canola meal on total tract digestibility and milk production. The digestibility trial, conducted on 21 Suffolk lambs, showed that apparent total tract DMD and CPD increased linearly as the inclusion level of both HFCM and canola meal increased (Table 8). The DMD and CPD were higher for canola meal at a 75% inclusion level compared to HFCM. There were no differences in NDF and ADF digestibility between the two treatments at all inclusion levels.

Milk production and composition of cattle fed canola meal, HFCM, and SBM were also compared in the previous study. It was found that protein supplement had no effect on actual or 3.5% FCM (Table 9). No differences were found in the composition of milk fat, lactose, or total solids between dietary treatments. The canola meal and HFCM fed animals produced lower milk protein than animals fed SBM, however milk protein yield was similar among all diets. This is most likely attributed to the fact that SBM based diets contained a higher crude protein content than HFCM or canola meal. This data suggests that HFCM could replace canola meal or SBM as a protein supplement for dairy cattle without causing adverse effects on milk production or composition.

Protein is provided to ruminants through a balance of rumen degradable protein and rumen undegradable protein. Canola meal has high RDP making it an intermediate source of RUP or by-pass protein (Mustafa et al. 2000). Subjecting canola meal to chemical or physical treatment can alter the RDP fraction. Physical treatment involves such things as dry heat treatment, moist heat treatment, jet sploding, and coating canola meal with materials that are resistant to ruminal degredation (blood, casein, and whey protein) (Mustafa et al. 2000). In 1993, McKinnon et al. studied performance differences of calves fed four different levels of RUP. The average daily gain was higher for calves fed 28% RUP compared to those fed 22% RUP (Table 10). Over the whole trial no performance differences were found between levels of RUP, aside from daily gain, whereby there was no added benefit of feeding more than 28% RUP or that supplied in the diet by canola meal itself.

Christensen and McKinnon (1993) suggest that canola meal can be used as the sole protein supplement in growing and finishing cattle. Relative to soybean based diets, milk production and composition are maintained when canola meal is used in dairy rations, suggesting its value in the dairy industry.

Table 8. Effect of high fiber and regular canonla meal inclusion rate in dehydrated alfalfa based diets on total tract nutrient utilization of sheep[1]

	Inclusion rate (% in diet)							Contrast (*P* value)[2]	
		High fiber canola meal (HFCM)			Regular canola meal (CM)				
	0	25	50	75	25	50	75		
Dehy alfalfa inclusion rate (%)	100	75	50	25	75	50	25	HFCM	CM
Apparent nutrient digestibility coefficient (%)									
Dry matter	59.2	62.8	63.2	65.5	62.4	65.2	67.5	.0001	.0001
Crude protein	63.8	69.7	72.4	75.5	70.8	74.4	78.7	.0001	.0001
Neutral detergent fiber	51.1	50.5	47.9	50.6	54	49.1	50.5	NS	NS
Acid detergent fiber	34.2	35.4	33.7	32.6	35.2	32.6	37.2	NS	NS

[1] Adapted from Mustafa et al. 1997.

[2] Significant polynomial contrast indicates linear effect of HFCM and CM inclusion rate (NS = not significant at P = 0.05). No quadratic effects detected.

Table 9. Effect of protein supplement on milk yield and milk composition of dairy cows[1]

	Protein source[y]			
	HFCM	CM	SBM	SEM
Milk yield (kg/d)				
Actual	33.8	33.4	33.6	0.52
3.5% FCM[z]	31.0	31.0	30.7	0.50
Protein	1.01	1.03	1.02	0.02
Fat	1.01	1.00	1.00	0.02
Lactose	1.62	1.61	1.61	0.02
Milk Composition (%)				
Protein	3.02[b]	3.01[b]	3.10[a]	0.02
Fat	3.03	2.95	3.02	0.06
Lactose	4.78	4.83	4.80	0.03
Total solids	11.85	11.76	11.97	0.08

[1] Adapted from Mustafa et al. 1997.

[a,b] Means in the same row with different letter are different ($P < 0.05$).

[y] HFCM = high fiber canola meal; CM = regular canola meal; SBM = soybean meal.

[z] FCM = Fat-correcte milk.

SEM = Standard error of the mean.

Table 10. Effect of rumen undegraded protein (RUP) level on performance of feedlot cattle[1]

	RUP (% of dietary protein)[2]				
	22	28	32	34	SEM
Dry matter intake, kg/d					
Day 0 to 56	8.2	8.3	8.0	8.1	0.20
Day 0 to finish	8.8	8.9	8.6	8.8	0.20
Daily gain, kg					
Day 0 to 56	1.19[b]	1.32[a]	1.26[ab]	1.21[ab]	0.03
Day 0 to finish	1.28	1.33	1.31	1.29	0.03
Feed:gain					
Day 0 to 56	6.95	6.27	6.38	6.71	0.18
Day 0 to finish	6.98	6.67	6.69	6.89	0.14

[1] Adapted from McKinnon et al. 1993.

[2] RUP level: 22%: urea based, 28%: canola meal based, 32%: heated canola meal/canola meal based, 34%: corn gluten meal/canola meal based.

[a,b] Means in the same row with different superscripts are different (P<0.05).

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WHOLESEED CANOLA (*BRASSICA CAMPESTRIS*)

Poultry

Whole canola seed contains a large amount of oil that is valued as an alternative energy source in broiler rations. Fasina and Campbell (1997) evaluated different inclusion levels of whole canola/pea (WCP) and whole canola/canola meal (WCC) blends on broiler performance. WCP at 0, 10, 20, or 30% or WCC at 0, 5, 10, or 15% were substituted for soybean meal and canola oil in both starter and finisher rations. The whole canola seed was mixed with peas at a 1:1 ratio or canola meal at a 3:1 ratio. The performance characteristics of broilers fed these rations are shown in Table 11. Overall, it was found that broilers fed the control diet were heavier than broilers fed any inclusion level of WCP or WCC. Feed intake was similar among all dietary treatments, although birds fed the control diets converted feed to gain more efficiently than birds fed any level of the blend-based diets. Due to the more pronounced performance differences of those animals fed WCC, the authors recommended that the inclusion level of WCC does exceed 10% of the diet.

Table 11. Performance of broiler chicks when fed different inclusion levels of whole canola/pea (WCP) and whole canola/canola meal (WCC) blends over a 40 day period[1]

	Body weight gain (kg)	Feed intake (kg)	Feed conversion (kg:kg)
WCP[2] (%)			
0	2.03[a]	3.90	1.87[a]
10	1.95[b]	3.97	1.98[b]
20	1.94[b]	3.95	1.97[b]
30	1.92[b]	3.83	1.95[b]
WCC[3] (%)			
0	2.03[a]	3.90	1.87[a]
5	1.94[ab]	3.93	1.95[b]
10	1.90[bc]	3.85	1.99[b]
15	1.83[c]	3.72	2.01[b]

[1] Adapted from Fasina and Campbell 1997.

[2] WCP contained 1:1 whole canola seed/whole peas.

[3] WCC contained 3:1 whole canola seed/canola meal.

[a,c] Means in the same column, within treatments, with different superscripts are significantly different ($P < 0.05$).

Swine

Inclusion levels of whole canola seed in diets of newly weaned pigs were evaluated by Shaw et al. (1990). Soybean meal served as the control diet and raw and jet-sploded canola seed were each added at 7.5, 15, or 30% of the diet to compose the other 6 diets. Table 12 illustrates the results of the performance trial. It was found that feed intake and average daily gain were significantly reduced when levels of 30% canola seed were included in the ration, regardless of treatement. When canola seed was added at 7.5 and 15%, the animals fed jet-sploded canola seed consumed less feed and did not gain as much weight as those fed raw canola seed. Animals fed soybean meal had higher nutrient digestibilities relative to those animals fed any amount of canola seed. It was concluded that jet-sploding did not increase the nutritive value of canola seed. The authors recommended that raw canola seed can be used at levels up to 15% of the total diet of newly weaned pigs.

Table 12. Effect of different inclusion levels of raw and jet-sploded (JS) canola seed on pig performance[1]

		Canola seed (%)					
		7.5		15		30	
	Control	Raw	JS	Raw	JS	Raw	JS
n. pigs	40	17	17	30	30	13	13
Feed intake (g/d)	661[a]	694[a]	672[a]	634[a]	633[a]	505[b]	509[b]
Daily gain (g/d)	474[a]	454[ab]	425[b]	478[a]	434[b]	415[c]	412[c]
Feed:gain	1.4	1.5	1.6	1.3	1.5	1.2	1.2

[1] Adapted from Shaw et al. 1990.

[a-c] Means in the same row with different superscripts are significiantly different ($P < 0.05$).

Ruminants

Whole canola seed can be treated to protect ruminal biohydrogenation of unsaturated fatty acids to ultimately change the fatty acid composition of milk. Tymchuk et al. (1998) found that treating whole seed canola with formaldehyde (FTCS) and heat (HTCS) resulted in a significantly higher amount of polyunsaturated fatty acids and long chain fatty acids compared to milk from cows fed untreated canola seed. No significant differences occurred in terms of any other milk traits among the diets. This data indicated that formaldehyde treatment protected ruminal biohydorgenation of unsaturated fatty acids when FTCS was included at 2% of the diet. The authors speculated that increasing the inclusion level of FTCS would further increase the level of unsaturated fatty acids in the milk.

Aldrich et al. (1997) conducted a similar study, whereby canola seed was chemically treated to increase the amount of unsaturated fatty acids reaching the small intestine and ultimately change the fatty acid composition of milk.

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FEEDING FROST-DAMAGED CANOLA SEED

General Description

Bell and colleagues (1982, 1984) at the University of Saskatchewan have conducted extensive research in the feeding value of frost-damaged canola seed, which is unsuitable for crushing or export. The immature seed, due to the frost damage, has smaller seeds with reduced oil content and a higher proportion of hull and fibre content. The nutrient content of frost-damaged canola seed is variable and it is recommended that each sample be evaluated to determine its value. Typically frost damaged canola seed contains 15 to 20 % crude protein, 20 to 38% oil, and 7 to 20% fibre. The nutrient composition and characteristics of canola seed is presented in Table 13.

Table 13. Nutrient composition and characteristics of whole canola seed (100% DM basis)

Nutrient	Average[1]	Average[2]
CP (%DM)	18.50	20.50
RDP (%CP)		78.7
RUP (%CP)		21.3
ADFIP (%DM)		1.3
NDFIP (%DM)		3.4
SP (%CP)		
NPN (%SP)		
ADF %		11.6
NDF %		17.8
Lignin (%DM)		2.7
Cellulose (%DM)		
Starch (%)		
A kd (%/hr)		
B_1 kd (%/hr)		
B_2 kd (%/hr)		
DE (kcal/kg) (swine)		
ME(kcal/kg) (swine)		
ME(kcal/kg) (poultry)		
TDN % (ruminants)	94.0	127.4
Energy Coefficients (Mcal/kg) (ruminants)		
DE	4.14[a]	5.60
ME	3.74[a]	4.92
NEm	2.62[a]	3.28
NEg	1.86[a]	2.38
NEl	2.18[a]	3.52
Fat (EE) %	36.2[a]	40.50
Ash %		4.60
Calcium %	0.25	0.44
Phosphorus %	0.60	0.68
Sodium %		0.03
Magnesium %		0.21
Copper (mg/kg)		12.00
Manganese (mg/kg)		48.00
Iron (mg/kg)		253.00
Zinc (mg/kg)		88.00
Selenium (mg/kg)		

[1] University of Saskatchewan 1993.

[2] NRC, Nutrient Requirements for Dairy Cattle 2001.

[a] NRC, Energy Prediction Equations, Nutrient Requirements of Dairy Cattle 2001.

Poultry

Research at the University of Gulelph (as quoted by Bell 1982) has shown frost-damaged seed can be included in broiler diets at levels up to 10% without altering chick performance. Similarly, the addition of up to 10% canola seed to laying hen rations did not alter egg production.

Swine

A study at the University of Saskatchewan found that growing pigs fed 30% frost-damaged canola seed had similar gains and feed efficiencies relative to those fed 0 percent (Table 14). Heat treatment, grinding, and pelleting of frost-damaged canola seed can be used to improve its nutritional value for swine feeding.

Table 14. Performance of pigs fed 0 to 30 percent of ground frost-damaged canola seed in the ration[1]

	Level of frozen seed in the ration (%)			
	0	10	20	30
Daily gain, kg	0.82	0.79	0.78	0.73
Feed:gain ratio	2.9	2.99	2.94	2.95

[1] Adapted from Bell et al. 1984.

Ruminants

The feeding value of frost-damaged canola seed for beef cattle was established using studies on the feeding value of screenings, assuming the two feeds would act similarly in beef cattle rations (Bell 1982). It was concluded that frost-damaged canola seed could be used at levels up to 20 to 30 percent in a finishing beef cattle diet. Due to the uncertainty of the content of frost-damaged canola seed it is advised that it not be fed to lactating cows as it may alter milk production, milk composition, and milk quality.

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FLAXSEED (*Linium usitatissimum*)

General Description

Flax is well adapted to and widely grown on brown and dark brown soil zones (Flax Crop Production 2000). As well it is quite suitable to be grown on the black and grey soil zones. Moisture is the most limiting factor with regard to yield (Flax Crop Production 2000). Table 1 indicates the production of flaxseed in western Canada with all Canadian flaxseed grown in this region. The amino acid and protein characteristics of whole flaxseed are illustrated in Table 2 and the nutrient composition and characteristics of are shown in Table 3.

Flax has a unique property whereby it is high in alpha-linolenic acid (ALA) content. ALA's are omega-3 fatty acids that are known to have positive effects in relation to heart health and autoimmune system (Flax Food Products 2000).

Table 1. Production of flaxseed in western Canada for years 1997 to 2000

	Thousands of tonnes			
	1997	1998	1999[r]	2000[p]
Alberta	31.8	39.4	39.4	17.8
Saskatchewan	508.0	680.8	711.2	469.9
Manitoba	355.6	360.7	271.8	205.7
Canadian total	895.4	1080.9	1022.4	693.4

[r] Revised

[p] Preliminary

Source: Canadian Grains Institute, Statistical Handbook 2000.

Table 2. Amino acid and protein characteristics of flaxseed (100% dry matter basis)

Amino Acid	Average Amount[1]	Average Amount[2]	Swine % Apparent Ileal Digestibility[2]
Arg	2.23	3.3	86
His		0.76	72
Ile	1.14	1.73	75
Leu	1.68	2.29	68
Lys	1.01	1.38	70
Met	0.55	0.66	76
Cys	0.94	0.66	
Phe		1.74	78
Tyr		1.14	
Thr	1.22	1.4	63
Trp	0.45	0.58	75
Val		1.93	74

[1] Racz 1996.

[2] NRC, Nurtient Requirements of Swine 1998.

Table 3. Nutrient composition and characteristics of whole flaxseed (100% DM basis)

Nutrient	Average[1]
CP (%DM)	24.80
RDP (%CP)	
RUP (%CP)	
ADFIP (%DM)	
NDFIP (%DM)	
SP (%CP)	
NPN (%SP)	
CF %	6.00
ADF %	9.06
NDF %	15.62
Lignin (%DM)	3.94
Cellulose (%DM)	5.60
Starch (%)	
A kd (%/hr)	
B_1 kd (%/hr)	
B_2 kd (%/hr)	
DE (kcal/kg) (swine)	
ME(kcal/kg) (swine)	
ME(kcal/kg) (poultry)	
TDN % (ruminants)	
Energy Coefficients (Mcal/kg) (ruminants)	
DE	
ME	
NEm	
NEg	
NEl	
Fat (EE) %	
Fatty Acids	
Linolenic	24.48
Linoleic	6.35
Oliec	8.81
Stearic	1.43
Palmitic	2.30
Ash %	3.94
Calcium %	0.25
Phosphorus %	0.56
Sodium %	0.03
Magnesium %	0.35
Copper (mg/kg)	11.32
Manganese (mg/kg)	32.82
Iron (mg/kg)	117.16
Zinc (mg/kg)	69.62
Selenium (mg/kg)	

[1] Racz 1996.

USE IN LIVESTOCK AND POULTRY DIETS

Poultry

Flax seems to be successful in the diets of laying hens, as the omega-3 fatty acids can be incorporated into the egg. Adding flax to the diet alters the fatty acid composition of the meat by incorporating omega-3 fatty acids into the meat (Flax Food Products, 2000). A study in Alberta on the effects of flaxseed in broiler meat composition found that there were increased levels of omega-3 fatty acids and linoleic acid in the lipid content of both white and dark meat. Researchers speculate that by incorporating flax into the diet of breeding chickens and sows, they can maternally transfer the omega-3 fatty acids onto their offspring, improving vigor and reducing mortality (Flax Food Products 2000).

Swine

Dr. Sam Baidoo, of the University of Minnesota, studied the effects of adding flax to the diets of gestating sows (Flax Focus, 2000). He added 5% flax to the diet of one group with 0% flax in the ration of the other group. The sows given the flax maintained their body weight and condition after lactation. As well, they had larger litters and their piglets had a higher average birth weight (Table 4). The piglets born to the flax fed sows gained weight faster than the piglets of the sows not fed flax. The flax fed sows averaged 11kg heavier and retained condition at weaning, increasing reproductive performance. It was found that the time between weaning and estrus was reduced in the flax fed sows.

Table 4. The effects on litter size and birth weight of sows fed 5% flaxseed

	5% Flax	0% Flax
Average litter size	11.5	10.8
Average birth weight (kg)	1.49	1.25

Source: Flax Council of Canada

Ruminants

Flaxseed can be used as a protein supplement in livestock rations, although it should be limited due to its high oil content. It has been recommended that flaxseed be restricted to 10 percent of the grain in livestock diets (Lardy and Anderson 1999).

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LINSEED (*LINUM USITATISSIMUM*) MEAL

General Description

Linseed meal is a by-product of the extraction of linseed oil from flaxseed and can be utilized by dairy cattle, swine, and poultry (Lardy and Anderson 1999). It serves as an excellent source of protein and varies, depending on the extraction process, from approximately 30 to 38 percent (Bath et al. 1980). Likewise, the oil content can vary with different processing methods and can range from 8 and 0.5 percent for expeller and solvent processing methods, respectively (Lardy and Anderson 1999). Linseed meal can be used as the sole protein supplement in livestock rations, although economics rarely allow it to exceed 10% of the concentrate mix (Bath et al. 1980). The nutrient composition and characteristics of linseed meal are presented in Table 5.

In addition to its use in the feed industry, linseed oil is also used extensively in industrial products such as paint, varnishes, and stains. The oil serves as a means of preserving and protecting wood, concrete, and flooring. Linseed oil is typically recognized for its use in linoleum flooring, whereby the oil is manufactured to form sheets of flooring (Flax Council of Canada 2000). Linoleum typically contains approximately 30 percent linseed oil (Flax Council of Canada 2000).

Table 3. Nutrient composition and characteristics of linseed meal (100% DM basis)

Nutrient	Solvent extracted	Mech. Extracted[1]
CP (%DM)[1]	35.50	34.50
RDP (%CP)[2]	47.0	
RUP (%CP)[2]	53.0	
ADFIP (%DM)[2]	1.1	
NDFIP (%DM)[2]	7.9	
SP (%CP)		
NPN (%SP)		
CF %[1]	9.0	9.3
ADF %[1]	14.0	14.5
NDF %[3]	26.5	
Lignin (%DM)[2]	8.30	
Cellulose (%DM)		
Starch (%)		
A kd (%/hr)		
B_1 kd (%/hr)		
B_2 kd (%/hr)		
DE (kcal/kg) (swine)[3]	3400.0	2945.0
ME(kcal/kg) (swine)[3]	3011.1	
ME(kcal/kg) (poultry)[4]	1565.0	
TDN % (ruminants)[1]	74.4	69.0
Energy Coefficients (Mcal/kg) (ruminants)[5]		
DE	3.28	
ME	2.86	
NEm	1.92	
NEg	1.28	
NEl	1.70	
Fat (EE) %[1]	1.10	5.70
Ash %[2]	6.50	
Calcium %[1]	0.40	0.44
Phosphorus %[1]	0.83	0.88
Sodium %[2]	0.09	
Magnesium %[2]	0.55	
Copper (mg/kg)[1]	26.00	26.00
Manganese (mg/kg)[1]	39.00	38.00
Iron (mg/kg)[1]	330.00	170.00
Zinc (mg/kg)[2]	69.00	
Selenium (mg/kg)[2]	1.05	

[1] Racz 1996.

[2] NRC, Nutrient Requirements of Dairy Cattle 2001.

[3] NRC, Nutrient Requirements for Swine 1998.

[4] NRC, United States-Canadian Tables of Feed Composition 1982.

[5] NRC, Energy Prediction Equations, Nutrient Requirements of Dairy Cattle 2001.

USE IN LIVESTOCK AND POULTRY DIETS

Poultry

Linseed meal has been shown to be deficient in adequate lysine to support growing poultry (Kratzer et al. 1947, as quoted by Wylie et al. 1972). It has been found that supplementing linseed meal with methionine and lysine can support similar gains and feed efficiency when replacing half the supplemental soybean meal. Relative to soybean meal these same parameters were slightly depressed when linseed meal, in combination with methionine and lysine, was used as the sole source of supplemental protein.

Linamarin can be present in immature linseed and under certain conditions may release prussic acid, which can be detrimental to poultry. Under normal manufacturing conditions, high temperature treatment should destroy this property. However, it is recommended that dietary levels of whole linseed do not exceed 3 percent of the diet.

Swine

Bell and Keith (1993) studied the effects of adding linseed meal to the diets of growing swine. In one study it was found that animals fed 5% linseed meal had poorer feed efficiencies than those fed 0% linseed meal, although over the whole trial there was no significant differences in terms of feed conversion between pigs fed 5% linseed meal and the basal diet. All other performance characteristics were not altered by dietary treatements.

Batterham et al. (1991) compared the nutritional value of conventional linseed meal, a low-linolenic acid linseed meal (Linola™), and soybean meal in growing swine rations. The nutritional value of linseed meal and Linola™ were similar and inferior in feeding value to that of soybean meal in swine diets. Pigs fed soybean meal numerically had higher feed intakes and converted feed to gain more efficiently than those fed linseed meal (Table 6). Consequently, average daily gains were higher for pigs fed soybean meal as the major supplemental protein.

Table 6. Performance evaluation of pigs fed wheat-based growing diets containing soybean meal (SBM), linseed meal (LSM), or Linola meal as the major dietary supplemental protein[1]

	Source of dietary protein			Contrast (*P* value)
	SBM	LSM	Linola	SBM vs linseed diets
Average daily gain (g/d)	793	695	681	< 0.05
Daily feed intake (g/d)	1690	1540	1490	> 0.05
Feed:gain ratio	2.15	2.22	2.22	> 0.05

[1] Adapted from Batterham et al. 1991.

Ruminants

Berge et al. (1993) found that animals fed linseed meal numerically had increased gains, fewer days to market, and leaner carcasses at slaughter compared to steers fed low, medium, or high levels of soybean-rapeseed meal. However, a sensory quality examination showed that meat from linseed meal fed animals had decreased tenderness and juiciness. As well, it was noted that the meat had an increased proportion of an undesirable "rancid" flavor. Therefore, the authors did not provide a conclusive inclusion level of linseed meal in steer diets.

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SUNFLOWER (*HELIANTHUS ANNUUS*) SEED AND MEAL

General Agronomics

Sunflower seeds are grown for use as seed, oil, and meals from the extraction of oil. Sunflowers require a long growing season and therefore may often be limited to certain areas of western Canada. Typically sunflowers need between 105 and 120 days to mature, depending on environmental conditions. Sunflower seeds can be utilized in human diets as confectionary seeds or vegetable oils used for cooking and salad oils. Table 1 illustrates the production of sunflower seed in western Canada, comprising the total amount of sunflower seed grown in Canada.

Table 1. Production of sunflower seed in western Canada for years 1997 to 2000

	Thousands of tonnes			
	1997	1998	1999[r]	2000[p]
Alberta	3.2	4.3	3.6	5.1
Saskatchewan	14.3	21.3	35.4	12.4
Manitoba	47.6	86.2	82.9	101.8
Canadian Total	65.1	111.8	121.9	119.3

[r] Revised

[p] Preliminary

Source: Canadian Grains Institute, Statistical Handbook 2000.

Nutrient Composition and Behavior

Sunflower seeds serve as a rich source of oil, providing energy, and contain a moderate amount of protein. The fatty acid composition of sunflower seeds is variable, however they do contain a relatively large amount of desirable unsaturated fatty acids, typically containing about 65% linoleic acid, which is higher than that found in soybeans (58%) (Schingoethe et al.1996). Sunflower meal is a product derived from the oil extraction of whole sunflower seeds. Hulled or dehulled seeds can be used to make sunflower meal, which makes the meal variable in nutrient content. The meal is generally rich in protein and energy, although levels are dependent on the addition of hulls. Dehulled sunflower meal has a protein content greater than that of canola meal but lower than soybean meal or meat and bone meal. Good quality sunflower meal can be equal in feeding value to soybean meal and can supply the sole supplemental protein source in beef cattle rations (Lardy and Anderson 1999). Tables 2 and 3 represent the amino acid and protein characteristics and the regression equations for predicting amino acids from protein for sunflower meal, respectively. Tables 4 and 5 illustrate the nutrient composition and characteristics of sunflower seeds and sunflower meal, respectively.

Table 2. Amino acid and protein characteristics of sunflower meal (100% DM basis)[1]

Amino Acid	Average Amount (%DM)	Swine % Apparent Ileal Digestibility	Swine % True Ileal Digestibilty	Poultry % True Ileal Digestibility
CP level	37.78			
Arg	2.98	85	87	83
Lys	1.31	79	83	78
Met	0.80	81	82	84
Cys	0.61	60	70	55
Thr	1.34	76	83	76
Trp	0.50	63	78	71
His	0.91	79	83	74
Ile	1.63	78	84	80
Leu	2.70	79	83	80
Phe	1.56	79	84	81
Tyr	1.12	77	83	79
Val	2.13	77	82	78

[1] Rhone-Poulenc Animal Nutrition 1993.

Table 3. Regression equations for predicting amino acid levels in sunflower meal from crude protein content[1]

Amino acid	Equation	R value
Methionine	%CP X 0.0247 - 0.0570	0.93
Methionine + Cystine	% CP X 0.0411 - 0.0160	0.94
Lysine	%CP X 0.0304 + 0.1720	0.86
Threonine	%CP X 0.0361 + 0.0360	0.95
Tryptophan	%CP X 0.0134 - 0.0490	0.92

[1] Degussa Company 1988.

Table 4. Nutrient composition and characteristics of sunflower seeds (100% DM basis)

Nutrient	Whole Seed[1]	Whole seed[2]
CP (%DM)	21.23	19.20
RDP (%CP)		
RUP (%CP)		
ADFIP (%DM)		1.9
NDFIP (%DM)		2.9
SP (%CP)		
NPN (%SP)		
CF %	13.40	
ADF %	17.52	16.7
NDF %	21.75	24.0
Lignin (%DM)	5.43	6.0
Cellulose (%DM)	12.00	
Starch (%)		
NFC		
A kd (%/hr)		
B_1 kd (%/hr)		
B_2 kd (%/hr)		
DE (Kcal/kg) (swine)		5.37
TDN% (ruminants)		122.3
ME (Kcal/kg) (poultry)		
ME (Kcal/kg) (poultry)		4.71
NEm (Mcal/kg) (ruminants)		3.13
NEg (Mcal/kg) (ruminants)		2.27
NEl (Mcal/kg) (dairy)		3.38
Fat (EE) %	45.71	41.9
Ash %	2.60	5.1
Calcium %		0.71
Phosphorus %		0.51
Sodium %		0.01
Magnesium %		0.34
Copper (mg/kg)		20.00
Manganese (mg/kg)		35.00
Iron (mg/kg)		144.00
Zinc (mg/kg)		53.00
Selenium (mg/kg)		1.80

[1] Adapted from Rodriguez et al. 1997.

[2] NRC, Nutrient Requirements of Dairy Cattle 2001.

Table 5. Nutrient composition and characteristics of sunflower meal (100% DM basis)

	Meal[1]	Meal[2]
CP (%DM)	29.78	28.40
RDP (%CP)		
RUP (%CP)		
ADFIP (%DM)		1.4
NDFIP (%DM)		5.5
SP (%CP)		
NPN (%SP)		
CF %		
ADF %	33.67	30.0
NDF %	47.10	40.3
Lignin (%DM)		9.5
Cellulose (%DM)		
Starch (%)		
NFC		
A kd (%/hr)		
B_1 kd (%/hr)		
B_2 kd (%/hr)		
DE (Kcal/kg) (swine)	2233.3	
ME (Kcal/kg) (swine)	2033.3	
ME (Kcal/kg) (poultry)		
TDN% (ruminants)		
Energy coefficients (Mcal/kg) (ruminants)		
DE		2.90
ME		2.24
NEm		1.49
NEg		0.92
NEl		1.38
Fat (EE) %	1.44	1.40
Ash %		7.70
Calcium %	0.40	0.48
Phosphorus %	0.96	1.00
Sodium %	0.02	0.04
Magnesium %	0.76	0.63
Copper (mg/kg)	28.89	32.00
Manganese (mg/kg)	45.56	45.00
Iron (mg/kg)	282.22	298.00
Zinc (mg/kg)	73.33	88.00
Selenium (mg/kg)	0.55	0.50

[1] NRC, Nutrient Requirements of Swine 1998.

[2] NRC, Nutrient Requirements of Dairy Cattle 2001.

USE IN LIVESTOCK AND POULTRY DIETS

Poultry

Human health concerns of rising cholesterol have led to an interest in the research of altering the fatty acid composition of egg yolks by feeding oilseeds rich in n-3 polyunsaturated fatty acids (n-3 PUFA), which play an important role in reducing egg cholesterol (Kinsella et al. 1990, as quoted by Jiang et al. 1991). Jiang et al. (1991) studied the effects of including n-3 or n-6 PUFA rich oilseeds in laying hen rations on the quality of eggs produced. Four diets were prepared to contain either 15% full-fat flax (FLAX), 18% high oleic acid sunflower seed (HOAS), 21% regular, high linoleic acid sunflower seed (HLAS), or 3% animal tallow (control). Overall, feeding full-fat flax and sunflower seeds to laying hens did not change the internal quality of eggs with respect to specific gravity or haugh units. Hens fed flax had had darker yolk color compared to hens fed all other dietary treatments. The results of two separate taste tests revealed that 36% of eggs from flax fed hens had a fishy or fish related flavor for unexplainable reasons (Table 6). Eggs from hens fed sunflower seeds did not have an altered taste compared to the control ration.

Rodriguez et al. (1997) studied the effects on broiler performance when including hulled full-fat sunflower seeds (HFFSS) in broiler rations. The 28 day experiment consisted of feeding diets containing 0, 5, 15, or 25% ground HFFSS in a mash form. Overall, there were no significant differences on broiler performance as the inclusion level of HFFSS increased (Table 7). Likewise, nutrient digestibility and AME values did not differ significantly among dietary treatments (Table 8). These results led Rodriguez and colleagues to conclude that HFFSS could be included in broiler rations up to 25% of the total diet without causing adverse effects on broiler performance or nutrient digestibility.

Table 6. Number and percentage of evaluations that reported fishy flavor in eggs from hens fed diets containing full-fat oilseeds[1]

	Laying hen diets[2]			
Study	FLAX	HOAS	HLAS	Control
Food Center (n = 36)				
Number	13	1	0	2
Percentage	36	3	0	6
University (n = 28)				
Number	10	0	0	0
Percentage	36	0	0	0

[1] Adapted from Jiang et al. 1991.

[2] Laying hen diets contained either 15% flaxseed (FLAX), 18% high oleic acid sunflower seed (HOAS), 21% regular high linoleic acid sunflower seed (HLAS), or 3% animal tallow (control). .

Table 7. Performance of broiler chicks fed on diets with graded levles of HFFSS[1] from 1 to 28 days of age[2]

	Dietary level of HFFSS (%)				SEM[3]
	0	5	15	25	
Body weight gain (g / 28 days)	935	904	900	900	12.5
Feed intake (g / 28 days)	1499	1363	1508	1420	21.6
Feed:gain	1.6	1.51	1.67	1.58	0.03

[1] HFFSS = hulled full-fat sunflower seeds.

[2] Adapted from Rodriguez et al. 1997.

[3] Standard error of the mean.

Table 8. Apparent digestibility of crude protein (%), crude fat (%), and AME_n (MJ kg^{-1} DM) of diets with graded levels of HFFSS[1,2]

	Dietary level of HFFSS (%)				SEM[3]
	0	5	15	25	
Crude protein	84.5	84.7	83.4	83.9	0.40
Crude fat	84.6	84.9	86.9	86.9	0.37
AME_n	13.51	13.55	13.68	13.45	0.07

[1] Adapted from Rodriguez et al. 1997.

[2] HFFSS = hulled full-fat sunflower seeds.

[3] Standard error of the mean.

Swine

Sunflower seeds that are not suitable for oil production can be utilized in swine diets at levels up to 10 percent. Hartman et al. (1985) conducted a study evaluating performance and pork acceptability of swine fed varying levels of sunflower seeds. The sunflower seeds were added to a corn-soybean meal based diet at 0, 5, 10, and 20 percent replacing equivalent amounts of corn and soybean meal. Overall it was found that the average daily gain was highest in those animals fed 5% sunflower seeds and was lowest for those fed 20 percent (Table 9). Feed intake was similar for those diets containing 0 and 5% sunflower seeds, which was significantly higher than the intake of pigs fed 10 or 20% sunflower seeds. The feed:gain ratio was not altered by dietary treatment (Table 9).

The effects of dietary sunflower seeds on taste panel evaluation showed that there were no significant differences in juiciness, tenderness, or overall acceptability of the meat at various inclusion levels of sunflower seeds (Table 10). Also tenderness was not significantly different among treatments when measured by the Warner-Bratzler shear test.

Sunflower meal can be used in poultry, swine and ruminant rations as a protein supplement to support good gains, increased milk production, and premium meat qualities. Studies have shown that equivalent or superior growth performance of growing pigs can be obtained when fed sunflower meal replacing 35 to 65 percent soybean meal, supplemented or formulated for lysine content (Table 11) (Stothers 1993).

Table 9. Performance charcteristics of pigs fed different levels of sunflower seeds[1]

	Sunflower seeds, %				
	0	5	10	20	SE
To 59 kg					
Average daily gain, kg[a]	0.78	0.86	0.79	0.74	0.13
Average daily feed, kg	2.26	2.23	2.05	2.12	0.37
Feed:gain	2.90	2.66	2.58	2.73	0.46
59 to 100 kg					
Average daily gain, kg[b]	0.78	0.78	0.71	0.69	0.14
Average daily feed, kg	2.53	2.57	2.32	2.32	0.31
Feed:gain	3.20	3.28	3.19	3.43	0.52
Overall					
Average daily gain, kg[a]	0.78	0.82	0.74	0.71	0.10
Average daily feed, kg[c]	2.41	2.41	2.20	2.20	0.20
Feed:gain	3.06	3.00	2.93	3.08	0.28

[1] Adapted from Hartman et al. 1985.

[a] Cubic response ($P < 0.05$).

[b] Linear response ($P < 0.01$).

[c] Cubic response ($P < 0.06$).

Table 10. Effect of dietary levels of sunflower seeds on taste panel acceptance of pork[1]

	Sunflower seeds, %				
Source	0	5	10	20	SE
Taste Panel					
Flavor[a]	5.66	5.74	5.73	5.58	0.37
Juiciness[b]	5.07	5.43	5.18	5.08	0.79
Tenderness[c]	5.35	5.41	5.41	5.21	1.07
Overall desirability[a]	5.40	5.57	5.44	5.37	0.59
Shear test, kg[d]	10.50	11.12	11.13	11.00	1.81

[1] Adapted from Hartman et al. 1985.

[a] Scale of 1 to 8, 1 = extremely undesirable to 8 = extremely desirable.

[b] Scale of 1 to 8, 1 = extremely dry to 8 = extremely juicy.

[c] Scale of 1 to 8, 1 = extremely tough to 8 = extremely tender.

[d] Kilograms of force required to shear a 2.54 cm core.

Table 11. Performance of grower finisher pigs fed different levels of sunflower meal (SFM) and soybean meal (SBM) in a barley based ration[1]

	Control SBM	1/3 SFM + 0.05% lysine	2/3 SFM + 0.13% lysine	SFM only
Feed intake, kg/d	2.11	2.22	1.82	1.73
Average daily gain, kg/d	0.69	0.73	0.67	0.52
Feed:gain ratio	3.34	3.25	3.24	4.21

[1] Adapted from Stothers 1993.

Ruminants

Sunflower seeds contain a large amount of highly unsaturated fatty acids in the fat source, which can be used to alter the milk composition of dairy cattle fed sunflower seeds. Table 10 illustrates the results of a study conducted by Schingoethe et al. (1996), whereby the effects of feeding two sources of unsaturated oilseeds, extruded soybeans (ESB) and rolled sunflower seeds (SFS), on milk yield and composition of dairy cattle were evaluated. Cows fed the supplemental fat diets produced more milk and had significantly higher yields of protein, fat, lactose, and SNF relative to animals fed the control diet, however, there was no significant difference between the ESB and SFS diets. Milk composition remained similar among cattle fed all treatments. Cattle fed ESB and SFS rations obtained increased levels of unsaturated fatty acids in the milk compared to those fed the control diet. This led the authors to suggest that both ESB and SFS can be used as dietary fat supplements to increase milk yield (Table 12) and the proportion of unsaturated fatty acids in the milk fat.

Table 12. Milk yield and composition of cows fed a control diet and diets containing supplemental fat from extruded soybeans (ESB) or sunflower seeds (SFS)[1]

	Diet				Contrast[a] ($P=$)	
Measurement	Control	ESB	SFS	SE	1	2
Yield, kg/d						
Actual	32.2	35.3	35.2	0.92	0.01	0.95
4% FCM	28.3	31.4	30.1	0.85	0.02	0.27
Fat	1.03	1.16	1.07	0.04	0.09	0.10
Protein	0.96	1.02	1.05	0.03	0.02	0.47
Lactose	1.52	1.69	1.68	0.05	0.01	0.86
SNF	2.66	2.91	2.93	0.08	0.01	0.87
Composition, %						
Fat	3.21	3.30	3.06	0.10	0.79	0.10
Protein	2.98	2.92	3.00	0.03	0.63	0.06
Lactose	4.71	4.79	4.79	0.04	0.09	0.94
SNF	8.26	8.27	8.38	0.05	0.30	0.13

[1] Adapted from Schingoethe et al. 1996.

[a] Contrasts: 1 = control vs ESB and SFS, and 2 = ESB vs SFS.

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PULSE AND SPECIALTY CROPS

CHICKPEA (*CICER ARIETINUM*)

General Agronomics

Chickpea is a pulse crop that grows well on brown and dark brown soil zones of Saskatchewan (Racz and Thacker 1999). There are two main commercial varieties of chickpeas known as Desi and Kabuli, generally classified depending on seed color, form, and type of origin (Mustafa et al. 2000). The Desi type has a thick, colored seed coat with colored flowers as opposed to the Kabuli type, which has a thin white seed coat with white flowers (Saskatchewan Agriculture and Food 1999). Saskatchewan chickpea production in 2000 was estimated at 370,700 tonnes, which is almost a 100% increase from 1999 production of 187,200 tonnes (Saskatchewan Agriculture and Food 2000).

Nutrient Composition and Behavior

Chickpeas are characterized by a high protein content, with an average of 22.67% for Kabuli and 23.53% for Desi chickpeas (Racz and Thacker 1999). Like field peas, chickpeas are relatively high in lysine but poorer in methionine and cystine. Chickpeas have a crude protein content slightly lower than lentil or field peas and consequently the lysine content in chickpea is lower than that of field peas (Racz and Thacker 1999). Chickpea protein is readily digested and of high solubility. The amino acid composition and regression equations for predicting amino acids are shown in Tables 1 and 2, respectively. The energy density of chickpea is related to the makeup of carbohydrate sources and fat or oil content. The Desi chickpeas contain larger quantities of carbohydrate as cellulose, lignin and other structural carbohydrates and less as starch or non-structural carbohydrates (Racz and Thacker 1999). This fact is especially important when formulating swine rations, as non-ruminants cannot readily utilize high fibre diets. The fat content of chickpea is higher than most cereals and that of some legumes such as field peas. This higher fat content contributes to the higher energy contained in Kabuli chickpeas as compared to Desi chickpeas. As well, Desi chickpeas have a higher quantity of NDF reducing its energy as a feedstuff (Racz and Thacker 1999). Older non-ruminant animals digest this fibre fraction more readily than younger animals. Table 3 illustrates the nutrient composition and characteristics of chickpeas.

As with other legumes, chickpeas cab contain anti-nutritional factors that may impair the utilization of nutrients by livestock (Mustafa et al 2000). These include protease inhibitor, amylase inhibitor, oligosaccharides, and polyphenols. Of most concern are the trypsin and chymotrypsin protease inhibitors, which may be heat treated to aid in the destruction of these anti-nutritional factors (Racz and Thacker 1999).

Table 1. Amino acid composition of chickpeas (100% dry matter basis)[1]

Amino Acid	Kabuli (%DM)	Desi (%DM)
CP level (%)	22.67	23.53
Arg	1.96	2.02
His	0.61	0.53
Ile	0.69	0.65
Leu	1.64	1.63
Lys	1.50	1.51
Met	0.30	0.31
Cys	0.37	0.38
Phe	1.18	1.12
Tyr	0.44	0.43
Thr	0.84	0.80
Val	0.77	0.71

[1] Racz and Thacker 1999.

Table 2. Regression equations for predicting amino acid levels in Kabuli and Desi chickpeas from crude protein content[1]

Amino Acid	Kabuli Equation	R-value
Lysine	%CP X 0.0443 + 0.5005	0.73
Methionine	%CP X 0.0042 + 0.0207	0.26
Methionine & Cystine	%CP X 0.0043 + 0.5702	0.07
Threonine	%CP X 0.0183 + 0.4222	0.44

Amino Acid	Desi Equation	R-Value
Lysine	%CP X 0.0369 + 0.6398	0.54
Methionine	%CP X 0.0054 + 0.1854	0.22
Methionine & Cystine	%CP X 0.0051 + 0.5760	0.12
Threonine	%CP X 0.0108 + 0.5478	0.19

[1] Racz and Thacker 1999.

Table 3. Nutrient composition and characteristics of chickpeas (100% dry matter basis)

Nutrient	Kabuli	Desi
CP (%DM)[1]	22.67	23.53
RDP (%CP)		
RUP(%CP)		
ADFIP (%DM)		
NDFIP (%DM)		
SP (%CP)		
NPN (% SP)		
CF%[1]	3.72	10.86
ADF %[1]	4.98	14.49
NDF %[1]	18.12	26.36
Lignin (%DM)		
Cellulose (%DM)		
Starch (%)		
NSC[1]	50.43	42.85
A kd (%/hr)		
B_1 kd (%/hr)		
B_2 kd (%/hr)		
DE (Kcal/kg) (swine)		
TDN % (ruminants)		
ME (Mcal/kg) (poultry)		
ME (Mcal/kg) (swine)		
NEm (Mcal/kg)		
NEg (Mcal/kg)		
NEl (Mcal/kg)		
Fat (EE) %[1]	5.53	3.96
Linolenic %[2]	2.00	
Linoleic %[2]	44.00	
Oleic %[2]	22.00	
Stearic %[2]	1.50	
Palmitic %[2]	10.00	
Ash %[1]	3.25	3.3
Calcium %[1]	0.13	0.15
Phosphorus %[1]	0.43	0.38
Sodium %[1]	0.01	0.015
Magnesium %[1]	0.17	0.21
Copper (mg/kg)		
Manganese (mg/kg)		
Iron (mg/kg)		
Zinc (mg/kg)		
Selenium (mg/kg)		

[1] Racz and Thacker 1999 - Average of 9 Kabuli varieties and 8 Desi varieties.

[2] Chavon et al. 1986, as quoted from Racz and Thacker 1999.

USES IN LIVESTOCK AND POULTRY DIETS

Poultry

Perez-Maldonado et al. (1999) evaluated the use of legume grains in laying hen diets. Chickpeas were studied and it was found that they were similar in feeding value to field peas and sweet lupins, and superior to faba beans (Table 4). Perez-Maldonado et al. (1999) recommended an inclusion level of 25% chickpeas in the diet of laying hens, due to the excellent performance obtained at this level. However, there was a significant increase in pancreas weight of chickpea fed hens, therefore a lower inclusion level of chickpeas in laying diets is warranted.

Table 4. Results of measurements made over 40 weeks on groups of 50 cages on diets containing 25 percent grain legume[1]

Treatments	Hen-d egg production (eggs/100 hen d)	Egg weight (g)	Egg mass (g/hen d)	Feed intake (g/d)	Feed conversion ratio
Chickpeas	82.4^{ab}	56.9^{a}	46.7^{a}	115.4^{b}	2.60^{b}
Field peas	84.1^{a}	55.9^{a}	46.9^{a}	116.3^{ab}	2.59^{b}
Sweet lupins	84.0^{a}	55.9^{a}	46.8^{a}	118.9^{a}	2.64^{ab}
Faba beans	80.7^{b}	53.7^{b}	43.2^{b}	113.3^{b}	2.80^{a}
SEM	1.36	0.44	0.83	1.3	0.075

[1] Adapted from Perez-Maldonado et al. 1999.

[2] Means in the same row with different superscripts are significantly different ($P < 0.05$).

Swine

Mustafa et al (2000) studied the difference in performance of pigs fed a soybean, chickpea, and field pea based diets. Table four illustrates the findings of this study. During the growing period the daily gain was better for the soybean meal as compared to the chickpea based meals. The field pea diets had similar daily feed intakes to both the chickpea and soybean meals. Feed conversion during the growing period was significantly poorer for pigs fed chickpea diets when compared to soybean and field pea diets. Although no significant differences were noted during the finishing period, there seemed to be a trend that the Kabuli chickpea diets did better with respect to pig performance. Overall, pig performance was not affected by dietary treatment. Castrates consumed more feed and gained faster than gilts.

Table 4. Performance of pigs fed chickpea-, field pea- and soybean meal-supplemented diets[1]

	Soybean meal	Desi chickpeas	Kabuli chickpeas	Field Peas	SEM[2]	Castrates	Gilts	SEM[2]
Grower Period (20.1-61.7kg)								
Daily Gain (kg)	0.80a	0.72b	0.70b	0.77ab	0.02	0.76	0.73	0.02
Daily Feed Intake (kg)	1.82	1.79	1.71	1.82	0.03	1.84	1.77	0.04
Feed Conversion	2.37b	2.52a	2.44ab	2.37b	0.04	2.43	2.41	0.03
Finishing Period (64.1-92.5kg)								
Daily Gain (kg)	1.11	1.07	1.12	1.09	0.03	1.19a	1.00b	0.02
Daily Feed Intake (kg)	3.38	3.09	3.18	3.2	0.09	3.50a	2.92b	0.07
Feed Conversion	3.04	2.91	2.85	2.94	0.07	2.95	2.92	0.05
Total Experiment (20.1-92.5kg)								
Daily Gain (kg)	0.9	0.83	0.84	0.88	0.02	0.90a	0.82b	0.02
Daily Feed Intake (kg)	2.39	2.22	2.2	2.29	0.06	2.40a	2.15b	0.04
Feed Conversion	2.64	2.68	2.61	2.6	0.04	2.65	2.61	0.03

[a,b] Means in the same row followed by different letters are significantly different ($P<0.05$).

[1] Adapted from Mustafa et al. 2000.

[2] SEM = pooled standard error of the mean.

Ruminants

There is limited data on the feeding value of chickpeas for ruminants. It is speculated that chickpeas would act similar to field peas in ruminant rations. The highly soluble protein of chickpeas may reduce the protein quality for ruminants (Mustafa et al. 2000). However, Mustafa et al. (2000) found that heat treatment reduced the ruminal degradability of chickpea protein, increasing the amount of protein available for post ruminal digestion.

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FABA BEANS (*VICIA FABA*)

General Agronomics

Faba beans are a cool season legume crop that must be planted early, as they require a longer growing season relative to other crops grown in western Canada. Faba beans should be processed before being fed to animals by such methods as rolling, cracking, or grinding (Massey and McKnight 1975). Faba beans can be harvested as silage and studies have shown that it has a comparable feeding value to grass-legume silages (Manitoba Department of Agriculture). During the ensiling process faba bean material becomes very dark in color and has a less than appealing odor to humans.

Nutrient Composition and Behavior

Faba beans are generally valued for their high protein content, although like most other pulse crops, they are low in sulfur containing amino acids but provide a satisfactory amount of lysine (Massey and McKnight 1975; Manitoba Department of Agriculture 1974). Faba beans contain about half the protein that soybean meal and have a slightly less metabolizable energy than that of barley, for swine. Table 1 represents the amino acid and protein characteristics and Table 2 illustrates the regression equations for predicting amino acids from crude protein. The nutrient composition and characteristics of faba beans are shown in Table 3.

Faba beans, like most other legumes, contain anti-nutritional factors (ANF); of particular interest are the condensed tannins (Helsper et al. 1996; Jansman et al. 1995, Farrell et al. 1999). Bulter (1989, as quoted by Jansman et al. 1995) describes tannins as water soluble polyphenolic compounds able to precipitate proteins form aqueous solutions. Tannins can range in concentration of 0 to 3.5% of the seed testa weight, where they tend to accumulate (Kuhla et al. 1982, as quoted by Helsper et al. 1996). The presence of this ANF can lead to reduced feed intake, depressed protein digestibility, and decreased animal performance (Jansman et al. 1995). Breeding and selection of recent varieties have limited the amount of tannins present in faba beans, but at the expense of lower yields (van Norel 1985, as quoted by Helsper et al. 1996).

Table 1. Amino acid composition and protein characteristics of faba beans (100% DM basis)

Amino Acid	Average Amount[1]	Average Amount[2]	Swine % Apparent Ileal Digestibility[2]	Swine % True Ileal Digestibility[2]
CP level	23.72	29.19		
Arg	1.10	2.62	89	91
His	0.67	0.77	85	87
Ile	1.09	1.18	80	84
Leu	1.93	2.17	82	86
Lys	1.45	1.86	84	87
Met	0.17	0.23	73	81
Cys	0.30	0.37	65	76
Phe	1.14	1.18	78	85
Tyr	0.79	1.00	79	82
Thr	0.95	1.02	75	82
Trp		0.25	68	75
Val	1.21	1.31	78	82

[1] Perez-Maldonado et al. 1999.

[2] NRC, Nutrient Requirements of Swine 1998.

Table 2. Regression equations for predicting amino acid levels in faba bean seed from crude protein content[1]

Amino Acid	Equation	R Value
Lysine	%CP X 0.0598 + 0.1120	0.78
Methionine	%CP X 0.0072 + 0.0210	0.63
Methionine + Cystine	%CP X 0.0155 + 0.1290	0.68
Tryptophan	%CP X 0.0109 + 0.0540	0.71
Threonine	%CP X 0.0278 + 0.1920	0.88

[1] NRC, Nutrient Requirements of Swine 1998.

USES IN LIVESTOCK AND POULTRY DIETS

Poultry

Perez-Maldonado et al. (1999) studied animal performance of laying hens fed grain legume diets. Faba beans, field peas, chickpeas, and sweet lupins were included in the laying ration at 25 percent. Faba beans had the lowest hen-day production and smallest eggs, consequently the smallest daily egg mass (Table 4). Faba beans also had the lowest feed intake and poorest feed efficiency of all the grain legumes. All other grain legumes had minor performance variation but were statistically alike. Perez-Maldonado and colleagues (1999) speculated that faba beans did poorly compared to the other grain legumes possibly because of increased tannin concentrations in the hull.

Table 3. Nutrient composition and characterisitics of faba beans (100%DM Basis)

Nutrient	Average
CP %[1]	29.19
RDP %	
RUP %	
ADFIP %	
NDFIP %	
SP (%CP)	
NPN (%SP)	
CF %	
ADF %[2]	8.30
NDF %[2]	18.83
Lignin (%)[2]	0.59
Cellulose (%)	
Starch (%)	
NFC	
A kd (%/hr)	
B_1 kd (%/hr)	
B_2 kd (%/hr)	
DE (kcal/kg) (swine)[1]	3730.0
ME (kcal/kg) (swine)[1]	3500.0
ME (kcal/kg) (poultry)[3]	2926.0
TDN % (ruminants)	
Energy coefficients (Mcal/kg) (ruminants)	
DE	
ME	
NEm	
NEg	
NEl	
Fat (EE) %[1]	1.61
Ash %[1]	3.19
Calcium %[1]	0.13
Phosphorus %[1]	0.55
Sodium %[1]	0.03
Magnesium %[1]	0.17
Copper (mg/kg)[1]	12.64
Manganese (mg/kg)[1]	17.24
Iron (mg/kg)[1]	86.21
Zinc (mg/kg)[1]	48.28
Selenium (mg/kg)[1]	0.02

[1] NRC, Nutrient Requirements of Swine 1998.

[2] Perez-Maldonado et al. 1999.

[3] Manitoba Department of Agriculture.

Farrell et al. (1999) conducted a follow up study of these same grain legumes on broiler performance. Different inclusion levels of 0, 12, 18, 24, 30, and 36 percent were used during a starter trial (0 to 21 d) and grower trial (21 to 42 d). During the starter phase weight gain and feed intake of birds fed faba beans were not affected by inclusion level, although feed efficiency improved as the inclusion rate increased. Different inclusion levels of faba beans during the growing phase did not have significant differences on broiler performance. In this study faba beans gave excellent chick performance, suggesting that perhaps tannins did not have an adverse effect on the feeding value of faba beans. From this data, Farrell et al. (1999) recommended that 20% faba beans would be a safe inclusion level in broiler rations. Massey and McKnight (1975) suggest that faba beans can be used broiler, turkey, and layer rations up to a maximum of 20% without causing negative effects on performance.

Table 4. Results of measurements made over 40 weeks on groups of 50 cages on diets containing 25 percent grain legume[1]

Treatments	Hen-d egg production (eggs/100 hen d)	Egg weight (g)	Egg mass (g/hen d)	Feed intake (g/d)	Feed conversion ratio
Chickpeas	82.4^{ab1}	56.9^{a}	46.7^{a}	115.4^{b}	2.60^{b}
Field peas	84.1^{a}	55.9^{a}	46.9^{a}	116.3^{ab}	2.59^{b}
Sweet lupins	84.0^{a}	55.9^{a}	46.8^{a}	118.9^{a}	2.64^{ab}
Faba beans	80.7^{b}	53.7^{b}	43.2^{b}	113.3^{b}	2.80^{a}
SEM	1.36	0.44	0.83	1.3	0.075

[1] Adapted from Perez-Maldonado et al. 1999.

[2] Values with different superscripts are significantly different ($P < 0.05$).

Table 5. Effects of different inclusion levels of faba beans on weight gain, feed intake, and feed conversion ratio (g feed/g gain) of the starter and grower phase in broiler chickens[1]

	Starter phase (0 to 21 d)			Grower phase (21 to 42 d)		
Inclusion Level (%)	Weight gain (g)	Feed intake (g)	Feed conversion ratio	Weight gain (g)	Feed intake (g)	Feed conversion ratio
12.0	625	810	1.31^{a2}	1069	1992	1.99
18.0	651	822	1.27^{ab}	1126	2044	1.88
24.0	659	814	1.24^{ab}	1012	1927	1.93
30.0	687	818	1.20^{b}	1021	1911	1.94
36.0	699	818	1.17^{bc}	1041	1937	1.93

[1] Adapted from Farrell et al. 1999.

[2] Values with different superscripts in the same column are significantly different ($P < 0.05$).

Swine

Faba beans can be used successfully in swine rations if they do not exceed 20% of the grower ration and 30% of the finishing diet (Massey and McKnight 1975). A study done at Kemptville college showed that when faba beans were used as the sole protein source, there was a 10% reduction in average daily gain and feed efficiency (Massey and McKnight 1975). Studies conducted at the University of Manitoba showed that pelleting the ration increased feed intake and average daily gain in pigs (Manitoba Department of Agriculture 1974).

Dairy and Beef Cattle

Faba beans can be used as a protein supplement in dairy rations. Studies at the University of Manitoba have shown that faba beans can be used up to 35% in dairy rations without causing adverse effects on milk production or composition (Manitoba Department of Agriculture 1974). Up to 25% faba beans can be used in calf rations without causing adverse effects on growth or reducing feed intake (Manitoba Department of Agriculture 1974). Faba beans can be used in beef rations to supply energy and protein to the diet. Faba beans should be introduced slowly into the ration so that digestive upsets do not occur (Manitoba Department of Agriculture 1974).

Sheep

Faba beans can serve as a protein and energy source, without limitations, in lamb, ewe, or ram diets (Manitoba Department of Agriculture 1974). It is important that sheep receive adequate amounts of protein. If protein is limiting, there will be a reduction in feed intake and feed efficiency, which compromises such things as wool production, reproductive efficiency, and growth (Manitoba Department of Agriculture 1974). Faba beans are an excellent source of protein and energy for gestating and lactating ewes.

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FIELD PEAS (*PISUM SATIVUM*)

General Agronomics

The production of peas in Western Canada has been increasing rapidly over the last decade with the opening of the European feed market (Slinkard 1997). In fact, since 1985 Saskatchewan has been the leading province in pea production, producing about 60% of the Canadian pea crop (Slinkard 1997). Table one illustrates pea production in Canada for the last four years.

Table 1. The production of peas in western Canada, 1997-2000.

	Thousands of tonnes			
	1997	1998	1999[r]	2000[p]
British Columbia	4.1	9.1	5.7	10.9
Alberta	421.8	488.0	530.8	620.5
Saskatchewan	1158.0	1613.9	1623.4	2072.4
Manitoba	178.3	225.9	92.0	160.5
Canadian Total	1762.2	2336.9	2251.9	2864.3

[r] Revised

[p] Preliminary

Source: Canadian Grains Institute, Statistical Handbook 2000.

Nutrient Composition and Behavior

Peas are a good source of protein for all livestock and in some species can be used as part or all of the supplemental protein in the diet. Peas are especially rich in lysine, although they are relatively low in the sulfur containing amino acids, methionine and cystine (Marquardt and Bell 1998; Racz 1997). This characteristic makes peas a good complementary protein source to cereals or other protein sources that are high in methionine and cystine, but low in lysine (Marquardt and Bell 1988). Tables 2 and 3 show the amino acid and protein characteristics of peas and the regression equations used for predicting amino acids. Peas are considered highly digestible for both ruminants and non-ruminant animals, as they contain little lignin. Peas have a high starch content, making them a rich energy source. The digestible energy of peas for swine is similar to that of corn or wheat. On the other hand, the metabolizable energy of peas for poultry is lower than corn or wheat and more similar to that of barley, likely due to the higher levels of indigestible carbohydrate for poultry (Racz 1997). The mineral content of peas is similar to cereal grains in that they are low in calcium and reasonably high in phosphorus. The nutrient composition and other pea characteristics are shown in Table 4.

Peas, along with many other plants, are known to contain relatively small amounts of phytic acid (1.2%), which binds to phosphorus making it less available (Marquardt and Bell 1988). Many other so called "antinutritional" factors can be present in peas with trypsin inhibitors being the one of concern. These components can reduce the nutritional value of peas but are found at low levels in Canadian feed peas and pose no problems (Marquardt and Bell 1988). Antinutritional factors of peas differ with respect to variety,

growing conditions, and climate. Canadian peas are spring white flowered varieties known to be low in trypsin inhibitors.

Table 2. Amino acid and protein characteristics of peas (100% DM basis)

Amino Acid	Average Amount[1]	Swine % Apparent Ileal Digestibility[2]	Swine % True Ileal Digestibilty[2]	Poultry % True Ileal Digestibiliy[2]
CP level (%)	26.44			
Arg	1.56	85	87	90
His	0.80	82	85	87
Ile	1.22	73	77	84
Leu	2.00	76	80	86
Lys	1.77	80	83	87
Met	0.30	74	78	82
Cys	0.23	63	70	74
Phe & Tyr	1.93	76	79	86
Thr	1.04	68	76	83
Trp	0.27	68	75	82
Val	1.44	70	75	81

[1] Marquardt and Bell 1988.

[2] Rhone-Poulenc Animal Nutrition 1993.

Table 3. Regression equations for predicting amino acid levels in peas from crude protein content[1]

Amino Acid	Equation	R Value
Lysine	%CP X 0.0598 + 0.358	0.992
Methionine	%CP X 0.0075 + 0.065	0.935
Cystine	%CP X 0.0059 + 0.220	0.753
Tryptophan	%CP X 0.0077 + 0.010	0.913
Threonine	%CP X 0.0264 + 0.297	0.978

[1] Mosse 1990, as quoted from Carrouèe and Gatel 1995.

USES IN LIVESTOCK AND POULTRY DIETS

Poultry

Peas can be used in the diet of all classes of poultry supplying a good source of protein and moderate energy. Hickling (1997) reviewed research conducted by Ivusic et al. 1994 and concluded that the performance of laying hens fed peas was quite similar to hens fed corn/soy based diets. Only two major differences were found, that being at high levels of pea addition, eggshell quality was reduced and because peas are devoid of xanthophylls, additional coloring agent had to be added to produce a yellow yolk if desired (Table 5). Hickling (1997) has suggested a safe maximum inclusion level of 30% peas in poultry rations.

Table 4. Nutrient composition and characteristics of field peas (100% dry matter basis)

Nutrient	Average	SD
CP (%DM)[1]	25.3	
RDP (%CP)[7]		
RUP (%CP)[7]		
ADFIP (%CP)[2]	0.51	
NDFIP (%CP)[2]	0.40	
SP (%CP)[7]		
NPN (%SP)[2]	12.88	
CF %[1,3]	6.11	
ADF %[4]	8.10	
NDF %[4]	14.56	
Lignin (%DM)[3]	1.00	
Cellulose (%DM)[7]		
Starch (%)[3]	51.2	
NFC[5]	55.84	
DE (Mcal/kg) (swine)[6]	3.87	
TDN% (ruminants)[7]	87.0	
ME (Mcal/kg) (poultry)[6]	2.94	
ME (Mcal/kg) (swine)[6]	3.60	
NEm (Mcal/kg) (ruminants)[7]	2.09	
NEg (Mcal/kg) (ruminants)[7]	1.42	
NEl (Mcal/kg) (dairy)[7]	2.01	
Fat (EE) %[4]	1.09	
Ash %[4]	3.21	
Calcium %[8]	0.13	0.024
Phosphorus %[8]	0.42	0.016
Available phosphorus %[6]	0.15	
Sodium %[9]	0.04	
Magnesium %[9]	0.13	
Copper (mg/kg)[9]	10.11	
Manganese (mg/kg)[9]	25.84	
Iron (mg/kg)[9]	73.03	
Zinc (mg/kg)[9]	25.84	
Selenium (mg/kg)[9]	0.43	

[1] Marquardt and Bell 1988.

[2] Christensen and Mustafa 2000.

[3] From results of annual evaluations of UNIP-ITCF and Mosse, 1990.

[4] Prairie Feed Resource Center, Pea variety test - 108 Saskatchewan samples.

[5] NFC Equation, NRC, Nutrient Requirements of Dairy Cattle 2001.

[6] Rhone -Poulenc Animal Nutrition 1993.

[7] NRC, United States-Canadian Tables of Feed Composition 1982.

[8] Canadian Feed Information Center 1990.

[9] NRC, Nutrient Requirements of Swine 1998.

Table 5. Effect of pea inclusion level in layer diets from 22 to 58 weeks of age on performance[1]

Performance	Control	Peas, %			
		14.8	29.6	44.5	59.0
Egg production, %	88.0	85.0	87.0	86.0	84.0
Feed conv., kg/doz	1.53	1.55	1.51	1.56	1.56
Egg weight, g	60.90	61.50	60.60	61.50	61.20
Egg shell, Spec. Grav.	1.073	1.072	1.073	1.072	1.068

[1] Adapted from Ivusic et al. 1994, as quoted by Hickling 1997.

Swine

Peas serve as a high quality protein and highly digestible energy source in swine diets. Racz and Bell (1997) reviewed a 1993 study conducted by Castell and Cliplef. The feeding value of peas, canola meal, and pea-canola meal blends were compared to soybean meal. The pea-canola blends resulted in superior performance characteristics compared to the control diets (Table 6). Canola meal provides a good source of sulfur containing amino acids that complements the high lysine and energy content of peas, making it a suitable for swine rations. Peas can also be used quite successfully in weanling diets and breeding swine rations (Racz and Bell, 1997). Racz and Bell (1997) recommend maximal levels of 30% of the total diet for starters and no maximal limit for grower-finisher and breeding stock rations.

Table 6. Performance of growing and finishing swine on barley based diets containing peas, canola meal, and soybean meal[1]

Item	SBM[2]	CM[3]	Blend 1	Blend 2	Peas
INGREDIENTS, %					
Barley	82.4	78.7	70.9	63.0	54.9
Canola meal	-	18.7	12.4	6.1	-
Peas	-	-	14.1	28.3	42.5
Soybean meal	15.0	-	-	-	-
Other	2.6	2.6	2.6	2.6	2.6
NUTRIENTS					
Crude protein, %	17.7	17.4	16.4	16.2	16.4
DE, kcal/kg	3130	3050	3090	3140	3180
Lysine, %	0.74	0.73	0.73	0.76	0.81
Meth + cys, %	0.64	0.70	0.60	0.54	0.50
Threonine, %	0.57	0.61	0.57	0.53	0.50
PERFORMANCE					
Avg. daily feed, g	2900	2924	2891	2953	2771
Avg. daily gain, g	821	845	850	880	812
Feed/gain	3.53	3.46	3.40	3.36	3.41

[1] Castell and Cliplef 1993, as quoted by Racz and Bell 1997.

[2] SBM = soybean meal

[3] CM = canola meal.

Ruminants

Peas in ruminant diets, although not extensively used, are characterized by rapid ruminal degradability of protein and slow ruminal degradability of starch (Corbett 1997). In a study conducted at the University of Alberta, peas were fed to calves without any negative effects on performance (de Boer et al, 1991, as quoted by Corbett, 1997). There seems to be no upper limit in the amount of peas that can be used in the diet of calves (Corbett 1997).

Peas are known to have a low by-pass protein content as compared to canola and soybean meals. Heat treatment of pea protein can increase the undegraded portion, which can result in a greater amount of absorbable lysine that may aid in increased milk production (Christensen and Mustafa 2000). During early lactation, by-pass protein is most essential and as lactation progresses, the need for rumianl undegradable protein decreases (Corbett 1997). Khorsani et al. (1992) at the University of Alberta, found that peas could be successfully substituted for soybean protein in the diets of late lactation cows. Table 7 indicates that milk yield, 4% fat corrected milk, and dry matter intake were not significantly affected with increasing levels of peas in the diet. Due to slow starch digestion, peas serve almost as a 'buffer", helping to maintain a rumen pH suitable for optimal fibre digestion (Corbett 1997).

Table 7. Effect of substitution of pea protein for soybean meal protein on milk production and dry matter intake in late lactation dairy cows.[1]

	Pea Protein, %			
Performance	0	33	67	100
Milk yield, kg/day	20.7	22	21.4	21.7
4% FCM[2], kg/day	20.2	21.8	21.9	20.7
Dry matter intake, kg/day	21.2	21.5	21.9	21.6

[1] Khorsani et al. 1992 as quoted from Corbett 1997.

[2] Fat Corrected Milk

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LENTILS (*LENS CULINARIS*)

General Description

Lentils are a cool-season pulse crop commonly grown for use in the human food market. Lentils that are not salable for human consumption, due to such things as frost or damaged seeds, can be utilized in livestock and poultry diets. Typically there are two types of lentils grown in western Canada; the predominant large-seeded Chilean and the smaller seeded Persian. Lentils can be grown on all soil types, but are best suited for the Brown and Dark Brown soil zones (McVicar et al. 1998).

As lentils are becoming increasingly popular, production in western Canada is proportionately growing. In fact, Canadian lentils are grown exclusively in western Canada, with approximately 900,000 tonnes produced annually, as seen in Table 1.

Table 1. Production of lentils in western Canada

	Thousands of tonnes			
	1997	1998	1999[r]	2000[p]
Alberta	8.8	8.0	12.4	9.9
Saskatchewan	365.1	465.8	702.6	888.1
Manitoba	6.1	5.9	8.8	16.1
Canadian Total	380.0	479.7	723.8	914.1

[r] Revised

[p] Preliminary

Source: Canadian Grains Institute, Statistical Handbook, 2000

Nutrient Composition and Behavior

Lentils contain a relatively high amount of protein and are rich in lysine, whereby they can be used to accompany low-lysine cereal grains in diets, similar to most other pulse crops. Lentils are low in sulfur-containing amino acids, which may become limited when lentils are used as the main protein supplement. The nutrient composition and characteristics of lentils are presented in Table 2 and the amino acid composition and protein digestibilities are illustrated in Table 3.

Table 2. Nutrient composition and characteristics of lentils (100% DM Basis)

Nutrient	Average	SD
CP (%DM)[1]	25.7	
RDP (%CP)		
RUP (%CP)		
ADFIP (%DM)		
NDFIP (%DM)		
SP (%CP)		
NPN (%SP)		
ADF %[2]	9.7	
NDF %[1]	32.4	
Lignin (%DM)		
Cellulose (%DM)		
Starch (%)		
A kd (%/hr)		
B_1 kd (%/hr)		
B_2 kd (%/hr)		
DE (kcal/kg) (swine)[3]	3977.0	
ME (kcal/kg) (swine)[4]	3825.0	
ME (kcal/kg) (poultry)[4]	2741.0	
TDN% (ruminants)[2]	75.54	5.82
Energy coefficients (Mcal/kg) (ruminants)[5]		
DE	3.33	
ME	2.91	
NEm	1.96	
NEg	1.31	
NEl	1.73	
Fat (EE) %[1]	1.60	
Ash %[1]	2.60	
Calcium %[2]	0.23	0.09
Phosphorus %[2]	0.44	0.08
Sodium %[4]	0.02	
Magnesium %[4]	0.13	
Copper (mg/kg)[4]	11.24	
Manganese (mg/kg)[4]	14.61	
Iron (mg/kg)[4]	95.51	
Zinc (mg/kg)[4]	28.09	
Selenium (mg/kg)[4]	0.11	

[1] Bell and Keith 1986.

[2] Saskatchewan Feed Test Laboratory, 1990 Feed Summary.

[3] Marquardt and Bell 1988.

[4] NRC, Nutrient Requirements of Swine 1998.

[5] NRC, Energy Prediction Equations, Nutrient Requirements of Dairy Catttle 2001.

Table 3. Amino acid and protein characteristics of lentils (100% DM Basis)

Amino Acid	Average Amount (% DM)[1]	Average Amount (% DM)[2]	Swine % Apparent Ileal Digestibility[2]
CP level	27.16	27.41	
Arg	2.36	2.30	81
His	0.74	0.88	76
Ile	1.17	1.12	75
Leu	2.08	2.06	76
Lys	1.80	1.92	83
Met & Cys	0.47	0.51	79
Phe & Tyr	1.96	2.23	71
Thr	1.08	0.94	70
Trp	0.24	0.24	-
Val	1.36	1.43	72

[1] Marquardt and Bell, 1988

[2] NRC, Nutritional Requirements of Swine, 1998

USE IN LIVESTOCK AND POULTRY DIETS

Poultry

Lentils can be used as a protein and energy source in the diets of poultry. Daghir et al. (1983) evaluated the use of feeding gamma irradiated lentils to broiler chickens on performance. It was found that irradiation did not aid in increasing chick performance. Goatcher and McGinnis (1972) found that the addition of antibiotics and methionine to lentil-containing chick diets increased the growth rate and feed efficiency of birds.

Swine

Bell and Keith (1986) evaluated the performance of swine fed various inclusion levels of ground lentils in growing swine rations. Ground lentils were fed at levels of 0, 10, 20, and 30% of the diet. It was found that pigs fed 30% frost damaged lentils supported similar intakes, gains, and feed efficiencies relative to those fed no amount of lentils (Table 4). This data suggests that pigs can be fed up to 30% lentils in the diet to replace equivalent amounts of cereal grain and protein supplements without being detrimental to pig performance.

Table 4. Performance of pigs fed different dietary levels of frost damaged lentils over a period of 23 to 100 kg[1]

	Lentils (% diet)			
	0	10	20	30
Average daily feed intake (g/d)	2.53	2.47	2.56	2.58
Average daily gain (g/d)	0.82	0.83	0.86	0.86
Feed:gain ratio	3.09	2.99	2.99	3.00

[1] Adapted from Bell and Keith

Ruminants

Purroy et al. (1993) studied the effects of feeding different lentil diets containing 12, 15, or 18% crude protein on lamb performance. It was found that animals fed diets containing 12% crude protein had lower feed intakes, growth, and converted feed to gain less efficiently than lambs fed rations with higher crude protein content. In 1992, Surra and colleagues evaluated the efficiency of replacing soybean meal with 0, 50, or 100% lentils on lamb performance. The DM and OM digestibilities increased with increasing lentils in the diet, although the performance was depressed. With increasing levels of lentils in lamb diets feed intake, growth rate and feed efficiency significantly decreased, suggesting that the use of lentils in sheep diets may need to be limited.

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CANARY SEED (*PHALARIS CANARIENSIS* L.)

General Agronomics

Canary seed, a cool season crop, is widely used as the major feed ingredient in caged and wild bird diets (Slinkard et al. 1994, McVicar et al. 1996). The glossy yellow hull of canary seed should not be removed, as it is an attractant to birds (Manitoba Agriculture 1989). Keet and Elias are two varieties of canary seed that are recognized in Canada and both perform similarly in Saskatchewan soils (Slinkard et al. 1994). Canary seed requires the same amount of time to mature as wheat, although it is more prone to drought and more sensitive to heat relative to wheat. Canary seed grows well on soils where wheat grows well with the exception of drier areas whereby moisture retention is lower. It is recommended to seed early to allow for proper maturation of canary seed straw, which can become difficult to thrash if immature (McVicar et al. 1996).

Canary seed is grown extensively in Saskatchewan, accounting for an approximately 88% of the total canary seed production in Canada with the remaining 12% grown in Alberta and Saskatchewan. On a global scale, Canada produces more than half of the world's canary seed making Saskatchewan the largest exporter of canary seed internationally (McVicar et al. 1996).

Table 1. Production of canary seed in western Canada for years 1997 to 2000

	Thousands of tonnes			
	1997	1998	1999[r]	2000[p]
Alberta	8.6	6.4	6.8	5.0
Saskatchewan	201.8	152.0	153.5	148.6
Manitoba	24.9	7.6	13.4	17.2
Canadian Total	235.3	166.0	173.7	170.8

[r] Revised

[p] Preliminary

Source: Canadian Grains Institute, Statistical Handbook 2000.

Nutrient Composition and Behavior

The crude protein of canary seed greatly exceeds that of most cereal grains. In a trial conducted by Abdel-Aal et al. (1997) it was found that the average crude protein of Saskatchewan grown canary seed groat was 18.7%, which surpassed the crude protein content of wheat by 25 percent. Canary seed is comprised of a relatively large amount of starch and low amount of dietary fibre. The ash and fat content of canary seed is greater than that of most other cereal grains. Lysine may be limiting in canary seed, however it contains an exceptional amount of tryptophan, which is generally scarce in cereal grains, and would complement feeds that are devoid of tryptophan. The nutrient composition and characteristics of canary seed are shown in Table 2.

Table 2. Nutrient composition and characteristics of canary seed (100% DM basis)

Nutrient	Average
CP (%DM)	18.43
RDP (%CP)	
RUP (%CP)	
ADFIP (%DM)	
NDFIP (%DM)	
SP (%CP)	
NPN (%SP)	
CF %	
ADF %	13.78
NDF %	
Lignin (%DM)	
Cellulose (%DM)	
Starch (%)	
NFC	
A kd (%/hr)	
B_1 kd (%/hr)	
B_2 kd (%/hr)	
DE (Kcal/kg) (swine)	
TDN% (ruminants)	
ME (Kcal/kg) (poultry)	
ME (Kcal/kg) (poultry)	
NEm (Mcal/kg) (ruminants)	
NEg (Mcal/kg) (ruminants)	
NEl (Mcal/kg) (dairy)	
Fat (EE) %	6.73
Ash %	6.71
Calcium %	0.00
Phosphorus %	0.00
Sodium %	
Magnesium %	
Copper (mg/kg)	
Manganese (mg/kg)	
Iron (mg/kg)	
Zinc (mg/kg)	
Selenium (mg/kg)	

[1] University of Saskatchewan 2000.

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ANIMAL BY-PRODUCTS

BLOOD MEAL

General Description

Blood meal is a product consisting of clean, fresh animal blood and does not include extraneous material such as hair. The meal is a result of heating the blood at high temperatures for prolonged periods and then drying the product (King'ori et al. 1998). The method in which blood meal is processed determines the way it is to be utilized in animal diets. Blood meal can come in such forms as spray-dried, ring-dried, vat-dried, fermented dried, and cook dried. Blood meal contains a high level of crude protein, with an exceptionally high amount of lysine. The RUP value of blood meal is high with rumen escape values of 92.4%, which is significantly higher than that of meat and bone meal and feather meal (60.8 and 73.5%, respectively) (Klemesrud et al. 2000). The amino acid and protein characteristics of blood meal are presented in Table 1 and the nutrient composition is illustrated in Table 2.

Table 1. Amino acid and protein characteristics of blood meal (100% DM basis)[1]

Amino Acid	Average Amount (%DM)	Swine % Apparent Ileal Digestibility	Swine % True Ileal Digestibilty	Poultry % True Ileal Digestibiliy
CP level	94.4			
Arg	4.01	88	92	87
Lys	8.97	91	94	88
Met	1.06	89	96	90
Cys	0.88	83	91	77
Thr	4.29	88	94	87
Trp	1.18	88	94	85
His	5.97	91	92	84
Ile	0.97	77	88	80
Leu	12.21	89	82	86
Phe	6.79	90	93	87
Tyr	2.81	88	93	87
Val	8.81	89	91	85

[1] Rhone-Poulenc Animal Nutrition 1993.

Table 2. Nutrient composition and characteristics of blood meal (100% DM basis)

	Blood Meal		
Nutrient	Meal[1]	Meal[2]	Spray dried[3]
CP (%DM)	87.20	93.75	95.48
RDP (%CP)		25.0	
RUP (%CP)		75.0	
ADFIP (%DM)		0.94	
NDFIP (%DM)		0.94	
SP (%CP)		5.0	
NPN (%SP)		0.0	
ADF %			
NDF %		0.92	
Lignin (%DM)			
Cellulose (%DM)			
Starch (%)			
A kd (%/hr)		0.0	
B_1 kd (%/hr)		0.0	
B_2 kd (%/hr)		0.0	
DE (kcal/kg) (swine)	2993.0		3623.7
ME(kcal/kg) (swine)	2527.0		3166.7
ME(kcal/kg) (poultry)	3096.0		
TDN % (ruminants)	66.0	66.0	
Energy Coefficients (Mcal/kg) (ruminants)			
DE	2.91		
ME	2.49	2.39	
NEm	1.47	1.51	
NEg	0.85	0.91	
NEl	1.50		
Fat (EE) %	1.40	1.70	1.40
Ash %	5.80	2.62	
Calcium %	0.32	0.40	0.44
Phosphorus %	0.26	0.32	0.32
Sodium %	0.35	0.31	0.47
Magnesium %	0.24	0.04	0.12
Copper (mg/kg)	11.00	13.90	8.61
Manganese (mg/kg)	6.00	11.70	3138.71
Iron (mg/kg)	4064.00	2281.00	6.45
Zinc (mg/kg)	5.00	33.00	32.25
Selenium (mg/kg)	0.80	0.80	

[1] NRC, United States-Canadian Tables of Feed Composition 1982.

[2] NRC, Nutrient Requirements for Beef Cattle 1996.

[3] NRC, Nutrient Requirements for Swine 1998.

USE IN LIVESTOCK AND POUTLRY DIETS

Poultry

Poultry rations generally do not contain blood meal, as it performs similarly to soybean meal as a protein supplement (National Renderers Association 1998). However, many studies have been conducted that show the relevance of blood meal in poultry rations. Donkoh et al. (1999) studied the effects on bird performance when fed rations containing solar-dried blood meal (SDBM). The control diet contained fish meal and groundnut cake as the main protein source and the experimental diets contained levels of 2.5, 5, and 7.5% SDBM. The level of SDBM in the diet did not affect the amount of feed consumed by birds (Table 3). Broilers fed 5 or 7.5% SDBM gained more weight and converted feed to gain more efficiently than birds fed 2.5% SDBM or diets free of SDBM. These results suggest that levels of up to 7.5% SDBM can be used in poultry diets, replacing equivalent amounts of soybean meal protein, with superior results on bird performance.

Karunajeewa et al. (1989) found that the inclusion of 5% blood meal in laying hen rations significantly decreased bird performance (decreased rate of laying, decreased egg size, decreased feed intake) but at the same time significantly increased egg quality (increased height of albumean, haugh unit score, shell color).

Table 3. Effect of solar-dried blood meal (SDBM) on performance of broiler chickens over a period of 14 to 49 days[1]

	Level of SDBM (%)				
	0	2.5	5.0	7.5	SEM[2]
Feed intake, kg	3.76	3.72	3.76	3.74	0.02
Gain, kg	1.79b	1.78b	1.84a	1.82a	0.01
Feed:gain ratio	2.10a	2.09a	2.04b	2.05b	0.02

[1] Adapted from Donkoh et al. 1999.

[2] SEM = Standard error of the mean.

[a,b] Means in the same row with different superscripts are significantly different ($P < 0.05$).

Swine

The amount of blood meal that can be included in swine rations is dependent upon the method of processing and the stage of production of the animal. King'ori et al. (1998) compared the nutritive value of blood meal processed by two different methods, cook dried (CDBM) or fermented dried blood meal (FDBM), for growing swine. The blood meals were included in a balanced swine diet to replace soybean meals at 0, 50, or 100 percent. Table 4 illustrates the results of the performance test of pigs fed these rations. Pigs fed diets containing FDBM supported similar intakes, gains, and feed efficiencies relative to the control soybean based diet. However, reduced intakes and

gains were seen where CDBM replaced all of the supplemental soybean meal, although feed efficiency remained similar. Diets containing 50% CDBM had slightly lower performance levels compared to 100% soybean based diets. These results clearly suggest that processing blood meal by fermentation drying provided better performance for growing pigs and that it can successfully replace all of the supplemental soybean meal in the diet.

Balogun (1982) found that pigs given blood meal in the diet tended to consume more feed and grew faster and more efficiently relative to pigs not receiving blood meal in the ration. As the level of protein in the diet increased livewieght gain, feed intake, and feed conversion were improved.

Table 4. Performance of pigs fed different levels of protein supplement over a 42 day period[1]

	Diets[2]				
	100% SBM	50% FDBM 50% SBM	100% FDBM	50% CDBM 50% SBM	100% CDBM
ADFI, kg/d	1.626[a]	1.559[a]	1.235[ab]	1.421[ab]	0.909[b]
ADG, kg/d	0.656[a]	0.663[a]	0.509[a]	0.559[a]	0.304[b]
Gain:feed ratio	0.403[a]	0.425[a]	0.412[a]	0.393[a]	0.334[a]

[1] Adapted from King'ori et al. 1997.

[2] SBM = soybean meal; FDBM = fermented dried blood meal; CDBM = cook dried blood meal.

[a,b] Means in the same row with different superscripts are significantly different ($P < 0.05$).

Ruminants

Blood meal is an excellent source of rumen undegradable protein, which aids in improving milk production. Sandrucci et al. (1992) studied the effects of substituting roller-dried blood meal for soybean meal in lactating dairy rations on milk yields and composition. Blood meal was included at 2.5% of the basal diet. Feed intake, milk yield, and milk composition were not altered by the inclusion of blood meal in the ration, suggesting that it can be used in dairy rations at levels up to 2.5% of the diet.

Harvey and Spears (1989) evaluated the performance of growing cattle when including two different processed blood meals, vat-dried (VDBM) and ring-dried (RDBM), in corn-based rations. Blood meal was fed in combination with urea and compared to the feeding value of soybean meal as a protein supplement. It was found that cattle consuming VDBM gained less and had poorer feed efficiencies than those fed RDBM or soybean meal. Average daily gain and feed:gain ratios were similar among cattle consuming RDBM and soybean meal. This study suggests that processing methods alter the way blood meal is utilized in cattle diets, whereby RDBM performed better than VDBM and could potentially be used to replace 100% of soybean meal as a protein supplement in growing cattle rations.

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FEATHER MEAL

General Description

Feather meal is made from hydrolysis of clean, undecomposed feathers gathered from slaughtered poultry, resultant from high pressure steam processing. The processing methods used to obtain feather meal can alter the way it is utilized in livestock and poultry rations. Feather meal is rich in protein and is typically used in animal rations as a protein supplement has the potential to reach feeding values comparable to that of soybean meal or cottonseed meal. Feather meal is high in ruminal escape protein and is exceptionally rich in sulfur containing amino acids relative to other animal proteins. Feather meal can be used to supplement diets that are deficient in sulfur-containing amino acids, such as a legume-based ration. The amino acid composition and protein characteristics of feather meal are presented in Table 1 and the nutrient composition and characteristics are shown in Table 2.

Table 1. Amino acid and protein characteristics of feather meal (100% DM basis)[1]

Amino Acid	Average Amount (%DM)	Swine % Apparent Ileal Digestibility	Swine % True Ileal Digestibilty	Poultry % True Ileal Digestibiliy
CP level	93.3			
Arg	6.15	81	84	74
Lys	2.00	55	66	62
Met	0.58	63	73	67
Cys	3.93	70	72	53
Thr	4.36	64	80	64
Trp	0.47			46
His	0.63	61	72	44
Ile	4.69	82	86	74
Leu	7.71	79	82	71
Phe	4.47	82	85	74
Tyr	2.56	73	79	66
Val	7.84	79	82	71

[1] Rhone-Poulenc Animal Nutrition 1993.

Table 2. Nutrient composition and characteristics of feather meal (100% DM basis)

	Feather Meal		
Nutrient	Meal, Hydrolyzed[1]	Meal, Hydrolyzed[2]	Meal[3]
CP (%DM)	90.86	92.00	85.80
RDP (%CP)			30.0
RUP (%CP)			70.0
ADFIP (%DM)			27.5
NDFIP (%DM)			42.9
SP (%CP)			9.0
NPN (%SP)			89.0
ADF %			
NDF %			39.0
Lignin (%DM)			
Cellulose (%DM)			
Starch (%)			
A kd (%/hr)			0.0
B_1 kd (%/hr)			0.0
B_2 kd (%/hr)			0.0
DE (kcal/kg) (swine)	3215.1		
ME(kcal/kg) (swine)	2672.1		
ME(kcal/kg) (poultry)			
TDN % (ruminants)		72.8	68.0
Energy Coefficients (Mcal/kg) (ruminants)			
DE		4.05	3.00[a]
ME		3.32	2.46
NEm		2.29	1.57
NEg		1.60	0.97
NEl		2.15	1.55[a]
Fat (EE) %	4.95	4.60	7.21
Ash %		3.50	3.50
Calcium %	0.35	0.33	1.19
Phosphorus %	0.54	0.50	0.68
Sodium %	0.37	0.34	0.24
Magnesium %	0.22	0.22	0.06
Copper (mg/kg)	10.75	10.00	14.20
Manganese (mg/kg)	10.75	10.00	12.00
Iron (mg/kg)	81.72	76.00	702.00
Zinc (mg/kg)	119.35	111.00	105.00
Selenium (mg/kg)	0.74	0.69	0.98

[1] NRC, Nutrient Requirements for Swine 1998.

[2] NRC, Nutrient Requirements of Dairy Cattle 2001.

[3] NRC, Nutrient Requirements for Beef Cattle 1996.

[a] NRC, Energy Prediction Equations, Nutrient Requirements of Dairy Cattle 2001.

USE IN LIVESTOCK AND POULTRY DIETS

Poultry

Cabel and collagues (1987) fed varying levels of feather meal in finishing broiler rations to determine its effect on reducing abdominal fat in broilers. A significant reduction in abdominal fat occurred for those birds fed 4, 6, 8, or 10% feather meal compared to those fed 0 or 2 percent. It was found that all diets containing feather meal had increased crude protein and this was thought to be responsible for the reduction in abdominal fat of broilers.

Abdella et al. (1996) examined the effects of replacing soybean meal or fish meal protein with hydrolyzed feather meal on the performance of broiler chickens. Feed consumption and gains were similar among all diets at all inclusion leves. The authors recommended that hydrolyzed feather meal could be used to replace up to 75% soybean meal and 100% of fish meal as a protein source in broiler rations.

Swine

Chiba et al. (1996) found that adding feather meal, supplemented with lysine, to finishing swine rations resulted in improved carcass characteristics (increased longissimus muscle area, increased proportion of carcass lean, decreased rib backfat) compared to those fed a feather meal based diet not supplemented with lysine. However, when feather meal was added to soybean based diets at a level of 9.1%, increased feed intakes, gains, and improved feed efficiency were seen relative to pigs fed feather meal as the sole supplemental protein source. This indicates that feather meal is a valuable source of protein in swine rations, although it should be fed in combination with a plant protein source to obtain its maximum potential.

Ruminants

Goedken et al. (1990) studied the effects of adding blood to feather meal as a protein supplement for ruminants. It was found that the addition of blood after hydrolysis of feathers increased ruminal escape protein compared to feather meal alone. Gain of steers was significantly higher for feather meal with the addition of blood or blood meal compared to feather meal alone. Dry matter intake was similar among all diets, which suggested that animals fed feather meal in combination with blood or blood meal converted feed to gain more efficiently than feather meal alone. Including blood to feather meal prior to hydrolysis did not improve performance, as a result of lower ruminal escape protein.

Pate et al. (1995) found that heifers fed molasses containing feather meal gained faster, leading to heavier liveweights at breeding and increased pregnancy rates compared to those fed molasses diets containing urea. When diets were fed to steers, the addition of blood further improved gains. The authors concluded that feather meal provides a good source of ruminally undegradable protein and could be used to improve gains and reproductive performance of cattle.

Brown and Pate (1997) found that increasing the amount of protein supplied by feather meal, increased the average daily gain and improved feed efficiency compared to lower inclusion levels. It is speculated that the improved performance was a result of increased protein reaching intestinal digestions, hence by-passing rumen degradation.

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FISH MEAL

General Description

Fish meal can be used in all livestock rations and is commonly used in aquaculture and pet diets. The use of fish meal in these rations can be optimized by the complementation of vegetable protein, which helps to improve animal performance and quality. Fish meal is highly digestible and has a high content of crude protein with an excellent amino acid balance. Fish oil can be used for such things as a feed ingredient in aquaculture diets, paints and oils, pharmaceuticals, and in the food industry to make such things as margarine. The amino acid and protein characteristics and regression equations for predicting amino acid levels are presented in Tables 1 and 2, respectively. The nutrient composition and other characteristics of fish meal are illustrated in Table 3.

Table 1. Amino acid and protein characteristics of fish meal (100% DM basis)[1]

Amino Acid	Average Amount (%DM)	Swine % Apparent Ileal Digestibility	Swine % True Ileal Digestibilty	Poultry % True Ileal Digestibiliy
CP level	75.5			
Arg	4.05	91	93	86
Lys	5.50	91	93	85
Met	2.15	91	92	90
Cys	0.68	78	85	79
Thr	3.26	88	92	84
Trp	0.80			69
His	1.55	88	91	79
Ile	3.55	90	93	85
Leu	5.76	91	93	88
Phe	2.99	88	91	86
Tyr	2.42	87	90	85
Val	4.14	87	91	81

[1] Rhone-Poulenc Animal Nutrition 1993.

Table 2. Regression equations for predicting amino acid levels in fish meal from crude protein content[1]

Amino acid	Equation	R value
Methionine	%CP X 0.0391 - 0.6900	0.82
Methionine + Cystine	% CP X 0.0463 - 0.5710	0.78
Lysine	%CP X 0.1081 - 1.9980	0.86
Threonine	%CP X 0.0537 - 0.7420	0.85
Tryptophan	%CP X 0.0158 - 0.3380	0.76

[1] Degussa Company 1988.

Table 3. Nutrient composition and characteristics of fish meal (100% DM basis)

	Fish meals		
Nutrient	Menhaden[1]	Menhaden[2]	Meal[3]
CP (%DM)	66.70	67.71	67.90
RDP (%CP)			40.0
RUP (%CP)			60.0
ADFIP (%DM)			0.68
NDFIP (%DM)			0.68
SP (%CP)			21.0
NPN (%SP)			0.0
ADF %			
NDF %			2.0
Lignin (%DM)			
Cellulose (%DM)			
Starch (%)			
A kd (%/hr)			0.0
B_1 kd (%/hr)			0.0
B_2 kd (%/hr)			0.0
DE (kcal/kg) (swine)	3799.0	4097.8	
ME(kcal/kg) (swine)	3414.0	3652.2	
ME(kcal/kg) (poultry)	3110.0		
TDN % (ruminants)	73.0		73.0
Energy Coefficients (Mcal/kg) (ruminants)			
DE	3.22		
ME	2.80		2.64
NEm	1.67		1.73
NEg	1.06		1.11
NEl	1.67		
Fat (EE) %	10.50	10.21	10.70
Ash %	20.80		20.60
Calcium %	5.65	5.66	5.46
Phosphorus %	3.16	3.30	3.14
Sodium %	0.43	0.43	0.44
Magnesium %	0.16	0.17	0.16
Copper (mg/kg)	12.00	11.95	11.30
Manganese (mg/kg)	37.00	40.21	40.00
Iron (mg/kg)	524.00	478.26	594.00
Zinc (mg/kg)	162.00	159.78	157.00
Selenium (mg/kg)	2.40	2.28	2.34

[1] NRC, United States-Canadian Tables of Feed Composition 1982.

[2] NRC, Nutrient Requirements for Swine 1998.

[3] NRC, Nutrient Requirements for Beef Cattle 1996.

USE IN LIVESTOCK AND POULTRY DIETS

Poultry

Fish meal can be utilized by all classes of poultry and its inclusion has been known to increase the productivity of birds. Typically fish meal is included in poultry rations at a rate of 4 to 5% of the total ration (Ifoma 1975). Olorede et al. (1999) evaluated the effects on growth performance characteristics when supplementing broiler rations with fish meal on growth performance characteristics. The diet contained 20% shea butter cake as the major protein source, whereby fish meal and groundnut cake were added. It was found that the addition of fish meal increased feed intakes, gains, and improved feed efficiency relative to diets supplemented with groundnut cake. Abdominal fat of birds fed shea butter cake supplemented with fish meal were lower than those fed groundnut cake. These results indicate the importance that fish meal has in terms of feeding value for poultry.

Swine

The inclusion of fish meal in baby pig rations can serve as an excellent source of protein and can optimize growth and feed efficiency of weaning pigs. Similarly, the addition of fish meal to growing animal ration can aid in improving gains and feed conversion. Bergstrom et al. (1997) studied the effects of feeding fish meal and spray-dried animal plasma to weanling pigs on performance. Fish meal was included in the diets at 0, 2.5, or 5%, replacing equivalent amounts of soybean meal. Piglets fed 2.5% fish meal had increased gains and converted feed more efficiently to gain than those fed 0 or 5% fish meal, indicating that levels of up to 2.5% fish meal can be utilized in weaning rations. Stoner et al. (1990) found that the inclusion of fish meal in weanling pig diets increased daily intake and gains indicating the efficacy of fish meal in starting swine rations.

Ruminants

Mandell et al. (1997) fed cattle fish meal at levels of 0, 5, and 10% of the diet to determine the effects on performance. The inclusion of fish meal increased average daily gains and feed efficiency, although dry matter intake remained the same. Adding fish meal at 5% gave the best feed efficiencies and highest intakes relative to feeding fish meal at 10% of the diet. With increasing amounts of fish meal in the diets the level of n-6 fatty acids were also increased, however the meat quality of animals fed this level of fish meal is unknown.

Ouellet et al. (1997) found that supplementing growing cattle, consuming grass silage, with fish meal led to increased gains and feed efficiency, although dry matter intake of the steers remained the same, as seen by Mandell et al. (1997). It has been found that the inclusion of fish meal with supplemental barley for growing steers increased the amount of silage consumed relative to feeding barley alone (Mackie et al. 1988).

Fish meal has a low rumen degradability and can therefore serve as a good source of rumen undegradable protein, helping to increase milk production and improve milk quality. Burke and colleagues (1997) studied the effects on reproduction and milk performance when replacing blood, meal and bone meal, and corn gluten meal with fish meal. Fish meal, fed at 0.7 kg/d, improved pregnancy rates 120 days postpartum. Milk yield and milk protein content were increased by the inclusion of fish meal. It was also noted that cows in parity 5 or greater had increased milk fat yield and 4% fat corrected milk when supplemented with fish meal.

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MEAT AND BONE MEAL

General Description

Meat and bone meal consists of rendered mammal tissue, excluding blood, hair, hoof, horn, and hide trimmings. This type of meal is relatively high in protein (55% DM) and contains a considerable amount of minerals (32% DM). The way in which meat and bone meal is processed can change the way it is utilized by the animal. As with all other animal protein by-products, meat and bone meal contains a large amount of its protein as ruminal escape protein. However, it is on the lower end of the scale in terms of feather meal and blood meal (Klemestrud et al. 2000). The amino acid and protein characteristics of meat and bone meal are shown in Table 1 and the regression equations for predicting amino acids from crude protein are presented in Table 2. The nutrient composition and characteristics of meat and bone meal are illustrated in Table 3.

Table 1. Amino acid and protein characteristics of meat and bone meal (100% DM basis)[1]

Amino Acid	Average Amount (%DM)	Swine % Apparent Ileal Digestibility	Swine % True Ileal Digestibilty	Poultry % True Ileal Digestibilty
CP level	64.5			
Arg	4.29	85	87	83
Lys	3.28	79	83	78
Met	0.80	81	85	84
Cys	0.94	60	70	55
Thr	2.23	76	83	76
Trp	0.39	63	78	71
His	1.11	79	83	74
Ile	2.11	78	84	80
Leu	4.05	79	83	80
Phe	2.25	79	84	81
Tyr	1.50	77	83	79
Val	3.04	77	82	78

[1] Rhone-Poulenc Animal Nutrition 1993.

Table 2. Regression equations for predicting amino acid levels in meat and bone meal from crude protein content[1]

Amino acid	Equation	R value
Methionine	%CP X 0.0228 - 0.4390	0.74
Methionine + Cystine	%CP X 0.0387 - 0.7240	0.70
Lysine	%CP X 0.0729 - 1.0560	0.82
Threonine	%CP X 0.0488 - 0.8060	0.86
Tryptophan	%CP X 0.0139 - 0.4030	0.76

[1] Degussa Company 1988.

Table 3. Nutrient composition and characteristics of meat and bone meal (100% DM basis)

Nutrient	Average[1]	Average[2]	Average[3]
CP (%DM)	54.10	55.37	58.20
RDP (%CP)			45.0
RUP (%CP)			55.0
ADFIP (%DM)			1.83
NDFIP (%DM)			32.83
SP (%CP)			13.36
NPN (%SP)			26.50
ADF %		6.02	
NDF %		34.94	28.21
Lignin (%DM)			
Cellulose (%DM)			
Starch (%)			
A kd (%/hr)			0.0
B_1 kd (%/hr)			0.0
B_2 kd (%/hr)			0.0
DE (kcal/kg) (swine)	2440.0	2623.7	
ME(kcal/kg) (swine)	2346.0	2392.5	
ME(kcal/kg) (poultry)	2236.0		
TDN % (ruminants)	71.0		71.0
Energy Coefficients (Mcal/kg) (ruminants)			
DE	3.13		3.13[a]
ME	2.71		2.57
NEm	1.61		1.66
NEg	1.00		1.05
NEl	1.62		1.62[a]
Fat (EE) %	10.40	11.72	11.00
Ash %	31.50		21.30
Calcium %	11.06	10.74	9.13
Phosphorus %	5.48	5.35	4.34
Sodium %	0.77	0.67	0.80
Magnesium %	1.09	0.44	0.27
Copper (mg/kg)	2.00	11.83	21.40
Manganese (mg/kg)	14.00	18.30	174.00
Iron (mg/kg)	735.00	651.61	758.00
Zinc (mg/kg)	96.00	103.22	265.00
Selenium (mg/kg)	0.28	0.33	0.00

[1] NRC, United States-Canadian Tables of Feed Composition 1982.

[2] NRC, Nutrient Requirements for Swine 1998.

[3] NRC, Nutrient Requirements for Beef Cattle 1996.

[a] NRC, Energy Prediction Equations, Nutrient Requirements of Dairy Cattle 2001.

USE IN LIVESTOCK AND POULTRY FEEDS

Poultry

Processing methods of meat and bone meal alter the digestibility and bioavailability of amino acids. In 1998, Wang and Parsons fed broilers low and high quality meat and bone meal to evaluate the effects on digestibility and bioavailability of amino acids. Digestibility of lysine, methionine, and cystine were lower for birds fed the low quality meat and bone meal (71, 83, and 31 percent, respectively) compared to those fed high quality meat and bone meal (92, 91, and 71 percent, respectively). When birds were fed diets containing 10 or 20% high quality meat and bone meal and 10% low quality meat and bone meal, formulated to be equal in amino acid digestibility and bioavailabilty, growth performance was equal to those fed diets containing soybean meal as the protein supplement. This was not seen for diets containing 20% low quality meat and bone meal, suggesting that when high dietary levels of low quality meat and bone meal are fed, amino acid supplementation may be necessary to maintain broiler performance.

In contrast, Esteve et al. (1994) fed broiler chickens diets containing 0, 5, 10, or 20% meat and bone meal to evaluate the effects on digestibility. It was found that amino acid digestibilities were not influenced by the amount of meat and bone meal included in the diets, and therefore amino acid supplementation was not necessary.

Swine

Meat and bone meal can be used in swine rations but is often limited to 2.5 to 5% of growing, finishing, and sow rations. Meat and bone meal is not recommended for use in starter feeds. Evans and Leibholz (1976) evaluated the effects on digestibility and performance when weaned pigs were fed diets of soybean meal and meat meal in combination with bone meal of low, medium, and high calcium content. It was found that dry matter digestibilities were reduced when pigs were fed soybean or meat meal based diets with the addition of high calcium bone meal. When bone meal was added to soybean meal, growth rate was not affected at any calcium level, however, when fed in combination with meat meal, gains and feed efficiency were reduced. When low calcium bone meal was supplemented, no significant differences were found in terms of performance when combined with meat meal or soybean meal. This suggests that careful consideration should be taken when feeding meat and bone meal to young swine.

Ruminants

Due to the Eurpean outbreak of bovine spongiform encephalopathy (BSE), the institution of a ruminant-to-ruminant feed ban has been implemented across North America. As a precautionary method the ban prevents materials processed from the slaughter of cattle and sheep from being fed back to these animal to ensure that BSE does not enter into North American ruminants. However, meat and bone meal from non-ruminant species can be fed to ruminant animals with success.

Moran (1973) fed 5 supplemental levels of meat and bone meal to grazing weaned calves to evaluate the effect on growth performance. Five groups were fed meat and bone meal supplements of 0, 0.21, 0.43, 0.86, or 1.71 kilograms. Groups offered 0.21 or 0.43 kg consumed their rations from the start, although those offered 0.86 or 1.71 kg rejected the supplement until September. Intake of meat and bone meal significantly improved gains in August when cattle were consuming 0.37kg and in September with intakes of 1.36kg. In October, however, intakes of meat and bone meal beyond 0.86kg did not prove to be beneficial in terms of increased growth rates. Overall, the group receiving 0.85 kg of meat and bone meal responded the best.

Meat and bone meal provides an adequate amount of ruminal by-pass protein to lactating dairy cattle, which has been shown to aid in supporting similar or superior milk production as those cattle fed plant proteins, such as soybean meal. Bernard (1997) studied the effects of replacing 24.5% soybean meal with an equivalent amount of meat and bone meal, as a protein supplement for lactating dairy cattle, on milk production and composition. It was found that cows fed meat and bone meal consumed more feed and yielded more milk with lower milk fat percentage relative to cattle fed soybean meal. Similarly, Akayezu et al. (1997) found that milk yields and composition were similar among dairy cattle fed soybean meal or a protein supplement containing meat and bone meal, suggesting that meat and bone meal could replace soybean meal without affecting lactating cow performance.

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PLANT BY-PRODUCTS

CHAFF

General Description

Chaff is a low-quality crop residue that consists of glumes, hulls, unthreshed heads, short straws, leaf material, weed seeds, and whole or cracked grain seeds. Chaff can come from cereal, oilseed, and pulse crops. It is a readily available product as 1 ton of chaff is produced for every 4 to 6 acres of crop harvested. The production of chaff remains quite uniform when grain yields fluctuate, as the glumes are produced early while the grain in the head may never fill. Chaff is more easily fed than straw because it is less bulky and has smaller particles, although they are similar in feeding value. Chaff, like straw, cannot be fed alone as it does not provide adequate amounts of nutrients to meet cattle requirements. Therefore, chaff should be supplemented with additional protein, minerals, and vitamins to provide a nutrient balanced ration. During times of feed shortage, chaff has the potential to be an economical substitute. Due to the high fibrous nature of chaff, it is not recommended for use in non-ruminant rations.

Nutrient Composition and Behavior

The nutritional value of chaff is inconsistent because it varies upon the parent seed, amount of weed seeds, weather, moisture content, and the way in which it is collected. Cereal chaff is similar in feeding value to that of straw, although it has a higher crude protein content and more digestible crude protein. Similar to straw, chaff can be ammoniated to improve its nutritional value by increasing nutrient digestibility, intake, and crude protein content. When chaff is ammoniated the feeding value improves to that of medium quality hay. Of the cereal chaff, oats have the best feeding value. The nutritive values of various untreated and ammoniated chaffs are presented in Table 1. As seen from this table, the energy (TDN) and protein contents of chaff were increased by ammoniation, although the amount of ash was reduced.

Table 1. Average chemical analysis (Saskatchewan Feed Test Laboratory) of various untreated and ammoniated chaffs gathered form several Saskatchewan farms[1]

Straw type	CP	TDN	Ash	Ca	P
Wheat	7.3	40.8	11.0	0.62	0.09
Ammoniated wheat	20.7	56.4	9.6	0.62	0.08
Barley	6.3	38.7	10.8	0.76	0.11
Ammoniated barley	17.3	50.7	9.1	0.51	0.14
Canola	8.5	33.7	11.8	1.57	0.15
Ammoniated canola	14.6	37.9	8.1	1.12	0.08
Flax	11.2	45.6	9.4	1.04	0.19
Pea	9.7	49.5	29.9	1.49	0.17
Lentil	13.1	51.4	8.7	1.78	0.18

[1] Adapted from Rutherford and Gimby 1991.

Feeding Value

Rutherford and Gimby (1991) compared the feeding value of several different untreated and ammoniated chaffs to that of straw and silage. All diets were fed to cattle and performance characteristics were evaluated (Table 2). It was found that cattle fed ammoniated chaff had increased intakes and higher gains than cattle fed conventional silage, although the feed:gain ratio was lower for chaff. Similarly, cattle fed a combination of ammoniated chaff and silage had higher daily gains than those fed silage alone. Straw fed cattle had the highest gains and converted feed to gain more efficiently than all other dietary treatments.

Kernan (1987) evaluated the use of untreated and ammoniated canola chaff in the diets of cattle. It was found that cattle did not reject the ammonia treated canola chaff, suggesting that there were no palatability problems. The feeding value of ammoniated canola chaff was slightly lower than that of ammoniated wheat chaff. This lead the author to recommend that a combination of ammoniated wheat and canola chaff would be more efficient than feeding canola chaff alone, provided additional energy, protein, and minerals are supplemented.

Table 2. Performance of cattle fed crop residue roughage rations[1]

	Straw	Amm. Chaff	Amm. chaff/silage	Silage
Feed intake, kg	1263	1361	1308	1275
Average daily gain, kg/d	1.10	1.05	1.00	0.95
Feed:gain ration	2.78	3.12	3.04	2.98

[1] Adapted from Rutherford and Gimby 1991.

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GRAIN SCREENINGS

General Description

Dockage, referred to as coarse screenings, is the unwanted material removed during grain cleaning. Screenings include chaff, weed seeds, other grains, pieces of stem, and shrunken, oversized, or broken seeds. Screenings are classified as No. 1, No. 2, and refuse screenings. No. 1 screenings contain a minimum of 35% shrunken, oversized, or broken parent grains. This class of screenings has a high feeding value and is primarily used in the swine and poultry industries. No. 2 feed screenings have a higher amount of weed seeds than do No. 1 screenings. Refuse screenings include primarily chaff, small weed seeds, dust, and may contain up to 15% of the parent grain. Saskatchewan has an average of 3.5% dockage annually, which is about 700,000 tonnes of screenings. Adding screenings from Alberta and Manitoba, western Canada accumulates a total of 1.2 million tonnes of screenings per annum.

Nutrient Composition and Behavior

The composition of screenings will vary depending on the parent material. Grain screening pellets compare favorably to oats in terms of feeding value (Table 1). However, screenings contain less energy and more fat compared to wheat or barley grain. The higher fibre content of screenings may make them more suitable in ruminant rations. The nutrient composition of processed grain screenings is illustrated in Table 2.

Table 1. Nutrient content of grain screening pellets relative to other grains (DM basis)

Nutrient (%)	Barley	Screenings	Oats	Wheat
Protein	12.4	12.2-16.5	11.7	14.5
TDN	82.2	72.2-75.5	75.5	88.8
Calcium	0.05	0.3-0.4	0.07	0.07
Phosphorus	0.4	0.3-0.4	0.4	0.4
Crude Fibre	5.6	8.9-17.8	11.7	2.0
Fat	1.8	5.6-8.9	4.4	1.7

Source: Saskatchewan Feed Test Laboratory.

Table 2. Chemical analysis of processed grain screenings using the Cornell Net Carbohydrate Protein System

Nutrient	Average Amount	SD
CP	15.3	1.3
SP (%CP)	34.0	3.7
ADFIP (%CP)	7.9	1.5
ADFIP (%CP)	21.0	2.2
NDF	34.1	2.2
NSC	36.9	3.6
Starch	26.1	6.0
Fat	9.8	2.8
Ash	7.0	0.9

Processing

Feeding raw screenings is limited due to reduced utilization by animals, weed seed viability, and transport and handling problems. Commonly, screenings are pelleted for addition in animal rations to overcome these disadvantages. Approximately two times the amount of pelleted screenings can be transported than raw screenings. Grain screenings contain a variable amount of weed seeds, which have hard seed coats that may be resistant to digestion and consequently may remain viable unless processed. Often producers will not bring raw screenings onto their property for fear of spreading these weed seeds onto their land. Composting of manure prior to spreading it can reduce the risk of spreading weed seeds but not eliminate it. Grinding has proved to be an effective method to destroy seeds and pelleting will help with handling and improved animal acceptability. Grinds should not be too fine as this may predispose cattle to bloat. Recently, Racz and Hultgren (2000) have put forward a novel way of processing grain screenings on the farm. It involves separation of fines with processing different fractions separately.

Use in Ruminant Rations

Grain screenings are valued for their high protein and energy and are generally targeted for the beef industry because of the high fibre content. A study at the University of Saskatchewan found that when grain screenings were fed as the sole source of feed, both cattle and sheep readily accepted it. The energy value of the screenings for both cattle and sheep was 75% total digestible nutrients (Table 3). It was found that nutrient utilization of cattle fed grain screenings was superior to an oat grain/brome hay diet. In the sheep trial, screenings were found to have 90% of the energy and 26% more digestible nutrients than regular barley.

A study conducted at the University of Saskatchewan evaluated steer performance of screenings fed to medium and large framed animals compared to a barley silage based diet. The average daily gain was not different among diets or frame size of the cattle; however, the cattle consuming the screenings based diet ate less than cattle consuming the silage based diet (Table 4). This indicates that the animals fed screenings converted feed to gain more efficiently than animals consuming a silage based ration.

Another study conducted at the University of Saskatchewan fed cattle one of four diets based on grain screenings or barley grain in combination with two forage sources – barley silage and straw or brome hay and straw. It was found that the average daily gain was slightly higher for cattle consuming screenings than those eating the barley based diets, regardless of the forage source (Table 5). Feed intake was lowest for the barley grain/barley silage fed animals, although no significant differences in feed intake were found among the other dietary treatments. Feed conversion was similar among all diets except for the barley grain/brome hay diet, which had a poorer feed efficiency.

Table 3. Intake and digestibility of processed grain screenings by cattle and sheep

Parameter	Cattle	Sheep
Dry matter intake (kg/day)	8.48	2.27
DMI (% body weight)	2.2	4.3
Nutrient Digestibility (%)		
Dry matter	68.4	66.6
Crude protein	75.6	74.1
NDF	32.9	29.4
ADF	24.5	25.6
Energy	68.6	69.8
DE (Mcal/kg DM)	3.31	3.31
TDN % (DM basis)	74.5	75.0

Table 4. Performance of rwo biological types of cattle fed backgrounding diets based on conventional feeds vs. grain screening pellets

	Medium Frame		Large Frame	
Parameter	Diet 1[y]	Diet 2	Diet 1	Diet 2
ADG (lbs/day)	2.29	2.29	2.21	2.21
Feed intake (lbs/day)	16.6a	15.5b	16.2a	15.4b
Feed:gain	7.40a	6.90b	7.60a	7.00b

a,b Means with different letters differ (P < 0.05).

[y] Diet 1 consisted of 60% barley silage, 7% grass hay, 8% straw and 25% grain concentrate; Diet 2 consisted of 60% grain screening pellets, 25% grain concentrate, 7% grass hay and 8% straw (as-fed basis).

Table 5. Effect of grain screening pellets or barley in forage based backgrounding diets

	Diet[z]				
Parameter	1	2	3	4	SEM[y]
ADG (lbs/day)	2.16b	2.29a	2.18b	2.32a	0.026
Feed intake (lbs/day)	15.52b	16.45a	16.91a	16.98a	0.18
Feed:gain	7.18b	7.17b	7.76a	7.26b	0.11

a,b,c Means in the same row with different letters are significantly different (P<0.05).

[z] Diets: 1 - Barley concentrate/ silage/ straw

2 - Grain screening pellets/ brome hay/ straw

3 - Barley concentrate/ brome hay/ straw

4 - Grain screening pellets/ brome hay/ straw

[y] S.E.M. = Pooled standard error of the mean.

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OAT HULLS

General Description

Oat hulls are the by-products that remain after oat grain is dehulled during processing. Oat hulls constitute approximately 25% of the total weight of the grain and have good potential as feed for ruminants, due to the fibrous nature of hulls, which ruminant animals can readily digest. Oat hulls vary in composition depending upon the efficiency of the dehulling process. The hulls can provide alternate forage and fibre source in areas or diets where traditional fibre sources are expensive, of limited availability, or are not in forms suitable for use in rations. Oat hull fibre can also be useful in some non-ruminant rations as a laxative or bulking agent. Oat hulls provide a good source of energy for ruminants through fibre degradation and fermentation. Undehulled kernels or small pieces of groat remaining after processing can aid to increase the energy of the product. Chemical treatment of oat hulls, namely ammoniation, has been implemented as a means of increasing the digestibility of oat hulls with high hemicellulose content. The nutrient composition and characteristics of oat hulls are illustrated in Table 1.

Table 1. Nutrient composition and characteristics of oat hulls (100% DM basis)

Nutrient	Average
CP (%DM)[1]	4.50
ADFIP (%CP)[1]	0.71
NDFIP (%CP)[1]	0.60
SP (%CP)[1]	35.69
NPN (%CP)[1]	5.14
CF %[1]	32.20
ADF %[1]	42.00
NDF %[1]	75.20
Lignin (%DM)[1]	40.18
Starch (%)[1]	8.01
Estimated energy coefficients[2]	
TDN %	42.00
DE (Mcal/kg)	1.89
ME (Mcal/kg)	1.46
NEm (Mcal/kg)	0.58
NEg (Mcal/kg)	0.05
NEl (Mcal/kg)	0.91
Fat (EE) %[1]	1.95
Ash %[1]	6.50
Calcium %[1]	0.16
Phosphorus %[1]	0.18
Magnesium %[1]	0.09
Potassium %[1]	0.62

[1] Feed Analysis, University of Saskatchewan 1998.

[2] NRC, Energy Prediction Equations, Nutrient Requirements of Dairy Cattle 2001.

Feeding Value

As a forage source, oat hulls can be used for growing and finishing cattle and maintaining mature cows. Oat hulls can constitute up to 50% of the total forage to a maximum of 30% of the diet for growing cattle. Finishing cattle can be fed oat hulls as the sole forage source in addition to concentrate. Finishing cattle fed oat hulls as an energy source have been shown to produce a white firm fat cover, necessary for premium carcass grading.

Birkelo and Lounsbery (1994a) studied the value of adding oat hulls to high concentrate finishing cattle rations. A finishing diet consisting of 8% oat hulls was compared to diets containing 8% ground alfalfa hay or no amounts of roughage. Feedlot performance for all steers in all groups was very good and did not differ among dietary treatments. Aside from dressing percentage, which was significantly higher for cattle fed no amount of roughage, carcass characteristics were similar among treatments.

Birkelo and colleagues (1994b) evaluated the effects of ammoniating oat hulls as a method to increased their digestibility in growing cattle rations. Hulls were treated with various amounts of ammonia (NH_3) and water and it was established that the maximum effect was achieved with 3% NH_3 and 20% water. Birkelo et al. (1994b) found that the addition of NH_3 and water to oat hulls increased the in vitro dry matter digestibility of cattle (Table 2). Ammonia treatment also significantly increased the crude protein content and lowered the amount of NDF and lignin in the hulls (Table 2).

In 1994c, Birkelo et al. went on to determine the feeding value of ammoniated oat hulls in weaned calf diets. Calves were fed diets containing 50% brome hay, untreated oat hulls, or NH_3 treated oat hulls. The ammoniated oat hulls had similar chemical characteristics as found in the previous study by Birkelo et al. (1994b). Feed intake remained the same among all dietary treatments, although calves fed ammoniated oat hulls had significantly higher weight gains due to improved feed efficiency relative to calves fed untreated oat hull diets or brome hay (Table 3). This suggests that ammoniated oat hulls can serve as an effective roughage in starter calf rations.

Birkelo and Rops (1994d) conducted a follow-up study, whereby ground, ammoniated oat hulls were added to the diets of growing calves. The dry matter intake of cattle fed ground, ammoniated oat hulls was significantly lower than those fed alfalfa hay or unground, ammoniated oat hulls. However, feed efficiency was significantly improved by the addition of ground oat hulls leading calves to gain similarly to those fed other dietary treatments.

Table 2. Chemical analysis and in vitro dry matter digestibility (IVDMD) of alfalfa hay, untreated and 3% ammonia - 20% moisture oat hulls (OH)[1]

	Composition (% DM)				
Feed	CP	NDF	ADF	ADL	IVDMD
Alfalfa hay	21.18[a]	53.10[ab]	43.47[a]	7.72[a]	50.00[b]
Untreated OH	8.49[c]	58.97[a]	30.45[b]	5.48[b]	44.78[c]
3% NH_3-20% H_2O OH	13.72[b]	51.34[b]	28.49[b]	5.26[c]	63.98[a]

[1] Adapted from Birkelo et al. 1994b.

[a,c] Means in the same column with different superscripts are significantly different ($P < 0.05$).

Table 3. Performance of steers fed growing diets containing brome hay, untreated oat hulls, or oat hulls treated with ammonia[1]

	Brome hay	Oat hulls	NH3 - Oat hulls
Dry matter intake, kg/d	7.98	8.07	8.21
Weight gain, kg/d	1.09[a]	1.05[a]	1.24[b]
Feed:gain	3.33[c]	3.48[c]	3.02[d]

[1] Adapted from Birkelo et al. 1994c.

[a,b] Means in the same row with different superscripts are significantly different ($P < 0.01$).

[c,d] Means in the same row with different superscripts are significantly different ($P < 0.05$).

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BREWERS' GRAIN

General Description

Brewers' grains are a by-product of the beer brewing industry made from malt barley and are produced in a similar manner to that of distillers' grains. Brewers' grains serve as an excellent source of energy and protein for all classes of poultry and livestock. As a result of the brewing process, the protein from brewers' grains is less soluble making it an excellent source of intestinal protein for ruminants. It has been shown that brewers' grains, as a protein supplement, have an equal or superior feeding value to that of soybean meal for lactating dairy cattle (Murdock et al. 1981, as quoted by Ojowi et al. 1997). The energy value of brewer's grains varies with the brewing process and the additives used during brewing. The amino acid and protein characterisitics are represented in Table 1 and the regression equations for predicting amino acid levels of brewers' grains are shown in Table 2. The nutrient composition and characteristics of brewers' grains are illustrated in Table 3. Brewers' grains can be fed wet or dry, although they are not as palatable when fed dry.

Table 1. Amino acid and protein characteristics of wet brewers' grains (100% DM basis)[1]

Amino Acid	Average Amount (%DM)	Swine % Apparent Ileal Digestibility	Swine % True Ileal Digestibilty
CP level	28.8		
Arg	1.66	81	95
Lys	1.17	69	82
Met	0.49	74	90
Cys	0.53	67	77
Thr	1.03	70	81
Trp	0.28	73	83
His	0.58	70	84
Ile	1.11	81	89
Leu	2.26	73	88
Phe	1.33	81	92
Tyr	0.96	91	94
Val	1.37	73	86

[1] NRC, Nutrient Requirements of Swine 1996.

Table 2. Regression equations for predicting amino acid levels in brewers' dried grains from crude protein content[1]

Amino acid	Equation	R value
Methionine	%CP X 0.0250 - 0.1274	0.95
Methionine + Cystine	% CP X 0.0436 - 0.0575	0.93
Lysine	%CP X 0.0295 + 0.1795	0.73
Threonine	%CP X 0.0333 + 0.0730	0.98
Tryptophan	%CP X 0.0086 + 0.686	0.90

[1] Degussa Company 1988.

Table 3. Nutrient composition and characteristics of brewers' by-products (100% DM basis)

Nutrient	Wet brewers' grains	SD
CP (%DM)[1]	28.40	
RDP (%CP)[2]	40.9	
RUP (%CP)[2]	59.1	
ADFIP (%DM)[1]	3.55	
NDFIP (%DM)[1]	8.69	
SP (%CP)[1]	10.6	
NPN (%CP)[1]	8.7	
ADF %[1]	24.1	
NDF %[1]	64.1	
Lignin (%DM)[1]	5.00	
Starch (%)[1]	2.8	
A kd (%/hr)[2]	300.0	
B_1 kd (%/hr)[2]	38.0	
B_2 kd (%/hr)[2]	6.0	
TDN %[2]	70.0	
Energy Coefficients (Mcal/kg)[3]		
DE	3.38	
ME	2.69	
NEm	1.84	
NEg	1.21	
NEl	1.71	
Fat (EE) %[1]	7.60	
Ash %[1]	4.2	
Calcium %[3]	0.35	0.22
Phosphorus %[3]	0.59	0.10
Sodium %[3]	0.01	0.01
Magnesium %[3]	0.21	0.26
Copper (mg/kg)[3]	9.00	7.0
Manganese (mg/kg)[3]	49.00	13.0
Iron (mg/kg)[3]	247.00	270.0
Zinc (mg/kg)[3]	91.00	17.0
Selenium (mg/kg)[3]	1.06	

[1] Ojowi et al. 1997.

[2] NRC, Nutrient Requirements for Beef Cattle 1996.

[3] NRC, Nutrient Requirements of Dairy Cattle 2001.

USE IN LIVESTOCK AND POULTRY DIETS

Poultry

Brewers' grains can be effectively used in poultry rations. It has been found that birds grew faster and matured earlier when brewers' dried grains (BDG) was included at 20% in broiler rations (Thornton and McPherron 1962, as quoted by Kratzer and Earl 1980). Onwudike (1983) found that gains and carcass yields were not affected by the inclusion of 30% BDG in broiler diets, although the optimum feed efficiency was obtained when birds were fed 15% BDG.

Yeong and Faizah (1986) found that inclusion levels of brewers' grains above 10% of laying hen rations had an adverse effect on egg production. This led the authors to recommend the levels of brewers' grains in laying hen diets do not exceed 10% of the total ration.

Swine

Brewers' dried grains are relatively high in fibre content limiting its use in swine rations. It has been found that BDG can be included in growing swine diets at levels up to 50% of the protein supplement without significantly affecting rates of gain (Young and Ingram 1968, as quoted by Wahlstrom and Libal 1976). It is widely accepted that older animals can digest fibre more readily than younger animals, which led Wahlstrom and Libal (1976) to evaluate the reproductive performance of brood sows when fed different amounts of BDG. Three diets consisting of 0, 20, or 40% BDG (balanced for lysine) were fed to gestating sows. Results indicated that reproductive performance was not compromised through the addition of BDG into gestating sow diets (Table 4), suggesting that up to 40% BDG can be utilized in the diet of sows without affecting sow gestation or lactation performance.

Table 4. Reproductive performance of sows fed various levels of brewers' dried grains (BDG)[1]

	Level of BDG		
Item	0	20	40
n. live pigs/litter	11.1	11.9	11.3
n. pigs weaned/litter	7.9	8.4	8.2
Litter birth weight (kg)	14.6	14.7	14.4
Pig birth weight (kg)	1.32	1.22	1.31
Litter weaning weight (kg)	40.3	40.3	41.2
Pig weaning weight (kg)	5.03	4.81	5.03

[1] Adapted from Wahlstrom and Libal 1976.

Ruminants

Ojowi et al. (1997) established that steers fed wet brewers' grain, as a protein supplement, performed similarly to those fed wet distillers' grains and soybean meal and could replace either as the sole supplemental protein source. Shand et al. (1998) found that the cooking and sensory quality of beef was similar of animals fed wet brewers' grains compared to those fed SBM as the supplemental protein source. Inclusion levels of up to 25% in the dairy concentrate mix and 15 to 20% of the concentrate has been recommended in feedlot rations (Bath et al. 1980).

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DISTILLERS BY-PRODUCTS

General Description

Whole stillage is material present following the fermentation and distillation of cereal grains for ethanol production. Whole stillage can be further processed resulting in wet distillers grains and thin distillers solubles or thin stillage. Commonly distillers' by-products are dried to accommodate transportation resulting in distillers' dried grains or distillers' dried grains with solubles. Distillers' by-products are a concentrated source of digestible energy and protein for all sources of livestock. The application of heat during the drying process decreases the undegradable protein content of the dried by-products. The amino acid and protein characteristics of distillers' by-products are illustrated in Table 1 and the regression equations for predicting amino acid levels are shown in Table 2. The chemical composition of distillers' by-products is dependent on the type and variety of grain used for distilling and the efficiency of the fermentation process. The nutrient composition of wet distillers' grains is present in Table 3.

Of the cereal grains, wheat production in western Canada is most abundant and is most likely to be utilized for distilling due to its availability. All cereal grains can be used for distilling purposes and therefore the by-products of all cereal grains can serve as feed in livestock and poultry rations. Dietary levels vary depending on the composition of the by-product, the species fed, and the stage of production of each species.

Table 1. Amino acid and protein characteristics of corn distillers' grains and solubles (100% DM basis)[1]

Amino Acid	Average Amount (%DM)	Swine % Apparent Ileal Digestibility	Swine % True Ileal Digestibilty	Poultry % True Ileal Digestibiliy
CP level	30.0			
Arg	2.22	71	77	83
Lys	1.18	50	59	64
Met	1.68	72	75	78
Cys	1.19	55	60	64
Thr	2.26	56	65	68
Trp	0.34			60
His	1.44	55	61	60
Ile	3.02	67	73	77
Leu	11.53	75	79	83
Phe	4.38	75	79	85
Tyr	3.68	71	77	81
Val	3.32	61	67	73

[1] Rhone-Poulenc Animal Nutrition 1993.

Table 2. Regression equations for predicting amino acid levels in distillers' grains and solubles from crude protein content[1]

Amino acid	Equation	R value
Methionine	%CP X 0.0076 + 0.2873	0.73
Lysine	%CP X 0.0221 + 0.0092	0.94
Threonine	%CP X 0.0118 + 0.6153	0.70

[1] Degussa Company 1988.

USE IN LIVESTOCK AND POULTRY DIETS

Poultry

Hen performance and the interior quality of eggs were examined in birds fed distillers' dried grains with solubles (DDGS) (Benabdeljelil and Jensen 1989). It was found that the addition of 20 or 30% DDGS to laying hen ration (maize-soy based) did not alter egg quality. Performance was not affected when 20% DDGS was added. However, it was found that young hens produced smaller eggs and older hens had increased shell breakage when 30% DDGS was added to the basal diet. These results indicated that an inclusion level of 20% DDGS would be acceptable in laying hen rations.

Swine

Distillers' by-products from various sources of grains have been fed in swine rations. Nasi (1985) compared the feeding value of barley DDGS, rye DDGS, wheat DDGS, barley distillers' dried grains, barley distillers' solubles, and soybean meal in swine rations. All distillery by-products were numerically lower in terms of pig performance than soybean meal, but not significantly. This suggests that the use of distillers' by-products in swine rations can support similar performance characteristics as those fed soybean meal.

Ruminants

Ojowi et al. (1996) found that replacing thin stillage as a water source for cattle grazing crested wheatgrass improved the overall performance of cattle, particularly during the later part of grazing when the nutritive value of the pasture declined. Fisher et al. (1999) found that the addition of thin stillage to water increased nutrient digestibility and decreased the DMI of the basal diet, without significantly altering steer performance and carcass characteristics.

Table 3. Nutrient composition and characteristics of corndistillers' by-products (100% DM basis)

Nutrient	Wet distillers' grains
CP (%DM)[1]	28.40
RDP (%CP)[2]	45.1
RUP (%CP)[2]	54.9
ADFIP (%DM)[1]	1.56
NDFIP (%DM)[1]	12.43
SP (%CP)[1]	24.9
NPN (%CP)[1]	6.1
ADF %[1]	24.1
NDF %[1]	74.9
Lignin (%DM)[1]	7.79
Cellulose (%DM)[1]	
Starch (%)[1]	1.5
A kd (%/hr)[2]	300.0
B_1 kd (%/hr)[2]	17.0
B_2 kd (%/hr)[2]	7.0
TDN %[2]	90.0
Energy Coefficients (Mcal/kg)[2]	
DE	
ME	3.25
NEm	2.24
NEg	1.55
NEl	
Fat (EE) %[1]	6.60
Ash %[1]	2.70
Calcium %[2]	0.32
Phosphorus %[2]	1.40
Sodium %[2]	0.24
Magnesium %[2]	0.65
Copper (mg/kg)[2]	83.90
Manganese (mg/kg)[2]	77.60
Iron (mg/kg)[2]	560.00
Zinc (mg/kg)[2]	94.60
Selenium (mg/kg)[2]	0.40

[1] Ojowi et al. 1997.

[2] NRC, Nutrient Requirements for Beef Cattle 1996.

Fisher et al. (1999) conducted a trial evaluating the performance, carcass characteristics, and nutrient utilization of growing and finishing cattle fed water or wheat-based thin stillage diluted in water at three different levels of dry matter. Increasing the

thin stillage DM, increased the consumption of thin stillage and decreased the DMI of the basal diet as expected. Average daily gain and feed efficiency were similar among all treatments. Dietary treatment did not affect the carcass characteristics, although there was a trend for increased carcass fat when the dry matter concentrations of thin stillage increased. As the dry matter concentration of thin stillage increased in the basal diet, there was a linear increase in the apparent digestibility of DM, CP, NDF, and DE of the total diet. This data suggests that the addition of thin stillage to water increases nutrient digestibility and decreases the intake of the basal diet, without significantly altering steer performance and carcass characteristics.

In 1997, Ojowi et al. evaluated the nutrient degradability and performance of steers fed wet brewers' grains (WBG) and wheat-based wet distillers' grains (WDG). It was found that wheat-based WDG were more degradable than WBG, whereby the effective degradability of DM, CP, ADF, and NDF of wheat-based WDG exceeded that of WBG. The performance trial indicated that steers fed wheat-based WDG gained equivalently, consumed comparable amounts of feed, and converted feed to gain similar to that of steers fed WBG. The authors concluded that wheat-based WDG would be a good source of supplemental protein for growing and finishing cattle, although not as rich in by-pass protein as WBG.

Mustafa et al. (2000) evaluated the nutrient degradabilties of wheat-, rye-, triticale-, and barley-based thin stillage and distillers' grains. It was determined, by means of an in vitro study, that thin stillage and distillers' grains from barley had a lower nutritive value for ruminants relative to rye, wheat, or triticale.

Nicholas et al. (1998) evaluated the use of corn distillers' grains and soybean meal, supplemented with and without ruminally protected lysine and methionine, as a protein source on the performance of lactating dairy cattle. It was found that animals consuming corn distillers' grains had a higher DMI than those fed soybean meal, which served as the control ration. Milk yield was the higher for cows fed corn distillers' grains, even further so when supplemented with lysine and methionine. All other milk characteristics remained similar among all treatments, with the exception of milk protein yield and percentage, which was elevated with the addition of amino acid supplementation. This data suggests that corn distillers' grains can be used as the sole supplemental protein source in lactating dairy cow rations. Bath et al. (1980) have suggested including distillers' by-products at levels up to 25% of the concentrate mix in dairy rations.

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MOLASSES

General Description

Several forms of molasses are incorporated into livestock diets, including sugarcane molasses, citrus molasses, beet molasses, and wood molasses. Cane molasses is the most widely used and is produced from the manufacture of cane sugar from sugar cane. The incorporation of molasses in livestock diets serves many purposes and includes such uses as a palatability enhancing agent, a source of reducing dust, and a medium to carry vitamins, minerals, and other dietary supplements (Lardy and Anderson 1999). The nutrient composition varies slightly between the different sources of molasses, although it is generally a good source of energy and low in protein. The nutrient composition and characteristics of molasses are illustrated in Table 1. Molasses is used in minor proportions in livestock rations, often less than 10% of the total ration. The addition of excess molasses can lead to mixing problems or clogging of the mixing equipment.

USE IN LIVESTOCK AND POULTRY DIETS

Poultry

Molasses is becoming increasingly popular in poultry rations as an alternate source of energy. Waldroup (1981) reviewed literature that had been conducted on the feeding of cane molasses to all types of poultry. It was found, in a study conducted by Winter (1929), that levels up to 10% in broiler rations gave similar performance to those fed 0% molasses. Similarly, Ott et al. (1942) found that feeding laying hens levels of 0 to 6% cane molasses did not alter bird performance. Rossenberg and Palafox (1956) conducted a study whereby laying hens were fed diets containing up to 34.5% molasses. The inclusion level did not significantly affect egg production or egg weight, although eggs were slightly reduced at the highest inclusion level of molasses. Walker and Ross (1960) evaluated the results of a taste panel supplied eggs of hens fed various inclusion levels of molasses. No differentiation occurred between eggs from hens fed 0 or 15% molasses; however, eggs from hens fed 20 or 30% had lower scores, but were not deemed unacceptable. The articles reviewed by Waldroup (1981) suggest that molasses is an appreciable source of energy and can be used at levels as high as 35% in laying rations and up to 10% in broiler diets.

Swine

Molasses, as with poultry, can serve as an energy source in the diets of swine. Molasses can be mixed with other nutrient sources, such as blood meal, in swine rations. M'ncene et al. (1999) found that a fermented dried blood/molasses mixture could be incorporated in growing pig diets at levels up to 10% without significantly altering performance or nitrogen utilization. Sharda and Singh (1981) found that pigs fed 5% molasses had higher weight gains and increased carcass length compared to those fed 0% molasses in the ration.

Table 1. Nutrient composition and characteristics of cane molasses (100% DM basis)

Nutrient	Average
CP (%DM)[1,2,3]	5.80
RDP (%CP)[1]	100.0
RUP (%CP)[1]	0.0
ADFIP (%DM)[2]	0.0
NDFIP (%DM)[2]	0.0
SP (%CP)[1]	100.0
NPN (%CP)[1]	100.0
ADF %[2]	0.2
NDF %[2]	0.4
Lignin (%DM)[2]	0.00
A kd (%/hr)[1]	500.0
B_1 kd (%/hr)[1]	30.0
B_2 kd (%/hr)[1]	20.0
TDN %[2]	81.0
DE (kcal/kg) (swine)[3]	3364.0
ME (kcal/kg) (poultry)[3]	2585.0
Ruminant Energy Coefficients (Mcal/kg)[2]	
DE	3.48
ME	2.78
NEm	1.91
NEg	1.28
NEl	1.76
Fat (EE) %[2]	0.20
Ash %[2,3]	13.30
Calcium %[1]	1.00
Phosphorus %[1]	0.10
Sodium %[1]	0.22
Magnesium %[1]	0.42
Copper (mg/kg)[1]	65.70
Manganese (mg/kg)[1]	59.00
Iron (mg/kg)[1]	263.00
Zinc (mg/kg)[1]	21.00
Selenium (mg/kg)[1]	0.00

[1] NRC, Nutrient Requirements for Beef Cattle 1996.

[2] NRC, Nutrient Requirements of Dairy Cattle 2001.

[3] NRC, United States-Canadian Tables of Feed Composition 1982.

Ruminants

Umoh (1983) fed growing cattle molasses at 0, 5, 10, 15, 20, or 25 percent of the diet. It was found that the inclusion of molasses in the ration had no significant affects on weight gains, dry matter digestibility, and carcass yields. Perry et al. (1999) suggest that levels of molasses in ruminant rations should not exceed 15% of the ration as levels higher than this can disrupt rumen microbial activity. Bath et al. (1980) recommend levels of up to 15% in feedlot rations and approximately 3 to 5% in dairy rations.

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FORAGE CROPS

FORAGE QUALITY AND FEED ANYALYSIS

The evaluation of hays and silages for feeding value and purposes is not easy and requires the combining of both visual and chemical aspects of the forage. The single largest factor in determining forage quality is that of the stage of maturity at harvesting. While climate and harvesting conditions all impact on forage quality, initial quality of the forage is determined by maturity at harvest. With all forages as they mature the protein decreases, digestibility decreases, and the amount capable of being eaten by the animal also decreases. Forage appraisal methods generally attempt to quantify and measure theses aspects of forage quality and use those measurements to predict the forages feeding value.

Hays and silages are often evaluated by sight, smell, and fee. While there are definite limitations for measuring quality with visual appraisal, it is an important tool in assisting to evaluate forages. Color, leaf content, stems texture, stage of maturity, contamination from weeds, molds, or soils are examples of useful visual observations. These visual aspects are ones not readily determined in chemical forage analysis. Chemical forage analysis does, however, measure or predict important aspects of forage quality such as protein, digestibility, and animal intake not possible by visual methods. These chemical analysis methods and their use in evaluating forages and animals response are based upon actual feeding trials, which would be too time consuming and expensive to do on a routine basis. The objectives in any appraisal are to determine the two main aspects of forage quality that being the nutrient content and digestibility combined with the ability to be consumed or feed intake.

Feed analysis and proper interpretation of results are important in helping to understand the value of a forage and more importantly how that forage can be supplemented to maximize its use. To provide a minimal basis for hay or silage evaluation it is recommended that moisture, crude protein, TDN or energy, acid detergent fibre (ADF) and pH of a silage be determined. Optional and important further forage analysis would be mineral analysis (calcium and phosphorus), nitrate analysis, neutral detergent fibre (NDF), acid detergent insoluble nitrogen (ADIN), and neutral detergent insoluble nitrogen (NDIN).

PROCESSED ALFALFA PRODUCTS

DEHYDRATED PELLETS, SUN-CURED PELLETS, AND ALFALFA CUBES

General Description

Alfalfa forage is widely grown in Canada, particularly in western Canada. Processed alfalfa producers in Canada harvest alfalfa forage at the late bud to early bloom stage and process it into several distinct products, namely pellets and cubes. This processing is a necessary step to not only preserve nutrients, but also reduce bulk for lower transportation costs, increased ease of handling, and reduced waste in feeding (Racz 2000). The harvesting of the forage is closely monitored to ensure a high quality, uniform product for processing. Dehydrated alfalfa pellets, commonly referred to as dehy, are processed from alfalfa cut in the late bud to early flowering stage. The alfalfa is partially dried down in the field to 60 to 65% moisture, where it is coarsely chopped and moved from the field to the processing plant for artificial drying. The heat processing that occurs during drying, changes approximately 60% of the protein into the bypass form leading to more efficient use and digestion of the protein with ruminants. Sun-cured alfalfa pellets are derived from finely chopped alfalfa that has been allowed to naturally dry in the field. Due to natural drying, sun-cured alfalfa pellets have a lower amount of bypass protein and should be fed in situations where bypass protein is of less importance, such as in growing young replacement heifers (Racz 2000). Sun-cured pellets are of lower quality than dehy pellets, because of the natural field drying process (Racz 2000). Alfalfa hay cubes are similar to sun-cured pellets, although they are made from coarsely chopped alfalfa. Alfalfa cubes can be used as the major forage source in dairy rations due to the longer fibre length and larger particle size of the cubes. Dehy alfalfa is an excellent source of beta-carotene and often contains a higher content than sun-cured pellets. During the last stages of processing dehy alfalfa, ethoxyquin, an antioxidant is added to help retain the carotene and other vitamin contents (Racz 2000).

Nutrient Composition

Processed alfalfa products serve as an excellent source of protein and are highly digestible. They also possess a large amount of vitamins, minerals, and energy. Alfalfa products are an excellent fibre source for ruminants, used to maintain normal rumen fermentation. These characteristics of alfalfa products make it an ideal complement to low quality forages. However, the nutritive value of processed alfalfa is dependent upon the stage of harvest, weathering, and processing conditions and is subject to variation with changing factors. The nutrient composition and characteristics of processed alfalfa products are shown in Table 1.

Table 1. Nutrient composition and characteristics of alfalfa products (100% dry matter basis)

	Pellets			
Nutrient	Dehydrated	Sun-cured	Cubes	SEM
CP (%DM)[1]	18.85	16.00	15.32	0.21
RDP (%CP)				
RUP (%CP)				
ADFIP (%DM)[1]	1.76	1.52	1.26	0.24
NDFIP (%DM)[1]	6.63	5.30	4.19	2.03
SP (%CP)[1]	28.13	31.64	25.15	1.24
NPN (%CP)[1]	25.34	27.74	20.63	0.86
CF %[3]				
ADF %[1]	30.64	41.42	36.87	0.24
NDF %[1]	43.02	55.64	50.88	0.34
ADL (%DM)	7.94	8.87	7.07	0.20
Cellulose (%DM)				
Starch (%)				
Carbohydrate fractions (%DM)[1]				
A	28.72	20.38	23.02	0.43
B_1	9.00	9.00	6.00	0.00
B_2	17.33	29.17	29.73	0.56
C	19.05	21.28	16.95	0.44
True protein fractions (%CP)[1]				
Total	66.07	63.97	70.06	1.33
B_1	2.79	3.12	3.49	0.62
B_2	39.46	39.01	47.53	1.24
B_3	23.87	21.84	19.04	0.44
TDN %[3]	66.6	61.5	61.0	
Energy coefficients (Mcal/kg)[4]				
DE	2.94	2.71	2.69	
ME	2.52	2.29	2.27	
Nem	1.62	1.42	1.4	
NEg (Mcal/kg)	1.02	0.83	0.82	
NEl (Mcal/kg)	1.51	1.39	1.37	
Fat (EE) %				
Ash %				
Calcium %[3]	1.72		1.53	
Phosphorus %[3]	0.26		0.19	
Sodium %				
Magnesium %				
Copper (mg/kg)[3]	6.72		8.78	
Manganese (mg/kg)[3]	31.63		41.45	
Iron (mg/kg)				
Zinc (mg/kg)[3]	30.13		20.18	

[1] Mustafa et al. 1999

[2] Canadian Dehydrators' Association 1991.

[3] Saskatchewan Feed Test Laboratory. Summary of feed analysis for 1990.

[4] NRC, Energy Prediction Equations, Nutrient Requirements of Dairy Cattle 2001.

Feeding Value

Poultry

Researchers have found that feeding dehydrated alfalfa pellets to poultry improved egg and skin pigmentation and increased hatchability. Feeding laying hens dehy alfalfa pellets results in a darker yolk color and breeding poultry can have increased fertility and hatchability (Table 2). Recommended inclusion levels of dehy alfalfa pellets in broiler and layer rations are 1 to 2% of the total diet (Agriculture Canada 1986).

Table 2. Effect of dietary dehydrated alfalfa meal on egg production, fertility, hatchability, and yolk color in chickens[1]

Dietary dehydrated alfalfa (%)	Hen day production (%)	Feed per dozen eggs (kg)	Fertility (%)	Hatchability (%)	NEPA yolk score
8	76	2.24	91	89	4.9
12	75	2.19	85	94	5.5
16	74	2.14	87	94	6.1

[1] Adapted from Agriculture Canada 1986.

Swine

The Canadian Dehydrators' Association (1998a) reviewed the use of dehydrated alfalfa pellets and cubes in swine rations. Dehydrated alfalfa pellets provide an excellent source of lysine to swine, which is a limiting amino acid in pork production. The protein content of dehy pellets is more than adequate, which can be economically beneficial by reducing costly protein supplements such as soybean meal. In addition, dehy pellets provide and excellent source of minerals and vitamins in swine rations. Feeding dehy alfalfa pellets in gestating sow diets has shown to improve reproductive performance by increasing conception rates, reducing time between farrowings, and decreasing cull sows in the breeding herd (Table 3). Dehy alfalfa pellets contain a large amount of fibre that helps prevent constipation in pregnant sows. Research has shown that feeding dehydrated alfalfa pellets to breeding sows results in more live piglets at parturition and weaning (Table 3). It has been recommended that dehydrated alfalfa pellets can be used at rates of 5 to 20% of the total gestating sow diet and 5 to 10% of the total diet for growing-finishing swine (Canadian Dehydrators' Association 1998a).

Table 3. Effect of dietary inclusion of dehydrated alfalfa pellets on sow productivity and culling over three reproductive cycles[1]

	Sow gestation diet	
	Corn-based control	50% dehydrated alfalfa pellets
n of litters	53	62
Average n of live pigs per litter at birth	10.8	11.8
Average birth weight, kg	1.50	1.37
Average n of live pigs per litter at 14 d	7.7	8.9
n sows culled	15 (34%)	5 (11%)
Average gestation interval, d (weaning to farrowing)	135	130
Sow gestation, kg		
Weight gain to 90 d	26.3	16.8
Weight gain, 90 to 110 d	13.8	14.8
Sow lactation, kg		
Weight loss	6.6	3.4
Feed intake per day	4.95	5.11

[1] Adapted from Canadian Dehydrators' Association 1998a.

Beef

Dehydrated alfalfa products provide rates of gain and feed conversion values that are comparable to other protein supplements used in beef rations. Dehy alfalfa pellets are rich in selenium, which aids in preventing white muscle disease. Beef cattle can benefit from the high by pass protein of dehy alfalfa pellets resulting in greater gains of growing animals. Dehy alfalfa pellets pass quickly through the digestive tract, which allows greater amounts to be consumed resulting in faster and more efficient weight gains. Alfalfa cubes can be used in beef rations to reduce feed wastage, ease handling and storage, and supply a consistent product of consistent nutritive quality.

Kirkpatrick et al. (1984) evaluated the performance of steers fed dehy alfalfa in relation to other feeds. The average daily gain tended to be higher for those steers fed dehy pellets compared to steers fed alfalfa-brome hay, although not significantly (Table 4). The feed intake was highest for dehy fed steers and lowest for those animals fed hay. Feed efficiency did no differ between dehy, hay, and a combination of these feeds, but was significantly improved with the addition of concentrate.

The Canadian Dehydrators' Association (1998b) recommends that levels up to 15% dehy alfalfa pellets can be used in feedlot rations, 2 to 3 kg be used for beef cow and growing calf rations to supplement forage, and 1.5 to 2.0 kg be fed daily to show animals to provide a glossy hair coat. Alfalfa cubes can be used to provide the total roughage requirements for mature stock and growing cattle.

Table 4. Performance of steers fed several rations consisting of dehydrated alfalfa, hay, and barley[1]

	100% Hay	100% Dehy[2] alfalfa	50:50 Dehy/hay	50:50 Dehy/barley	SE
Average daily gain, gk/d	0.95	1.1	1.08	1.26	0.10
Dry matter intake, kg/d	6.34[d]	8.18[a]	7.41[b]	6.80[c]	1.84
Feed:gain ratio	6.8[ab]	7.6[a]	7.0[a]	5.4[b]	0.47

[1] Adapted from Kirkpatrick et al. 1984·

[2] Dehy = dehydrated.

[a-d] Means in the same row followed by different letters differ ($P < 0.05$).

Dairy

Research has shown that dehydrated alfalfa products are an excellent source of bypass protein for high producing dairy cattle. Up to 50% of the protein in dehydrated alfalfa products is ruminally undegradable and will pass to the small intestine for absorption there, resulting in higher milk production.

Christensen and Cochran (1983) studied the effects of substituting dehydrated (dehy) pellets for concentrate on milk production and composition of lactating dairy cows. The pellets were fed in two trials with two different forage sources. Brome-alfalfa hay and oat silage were the two forages used in trial one and two, respectively. Dehy alfalfa was included at 0, 3, and 6 kg dry matter, replacing an equivalent amount of concentrate in the ration. In the first trial it was found that milk yield and composition were maintained when dehy alfalfa pellets were fed, except for milk protein percentage, which decreased when the pellets were added (Table 5). Similar results were obtained for trial two, whereby the inclusion level of dehy alfalfa did not affect milk production and composition (Table 6). No additional differences were found when the results of the two trials were combined, although there was a tendency for higher 4% FCM and milk fat when 6 kg of dehy alfalfa was fed. From this data the authors suggested that dehy alfalfa pellets can be included in dairy rations up to 5.5 kg of dry matter or 25% of the total dry matter ration when used to replace concentrate.

In 1999, Mustafa et al. evaluated the chemical composition and ruminal degradability characteristics of three processed lucerne products; sun-cured pellets, dehydrated pellets, and cubes. Table 7 represents the digestibilites of the three processed alfalfa products. The dehy pellets had the highest soluble dry matter degradability and

EDDM followed by cubes and sun-cured pellets, respectively. Sun-cured pellets and cubes had similar rates of dry matter degradation, which was lower relative to dehy pellets. Soluble protein degradability was highest for dehy pellets, intermediate for sun-cured pellets, and lowest for cubes. The degradation rate of the slowly degradable fraction and the EDCP were similar for sun-cured pellets and cubes, which was lower than that of dehy pellets. The dehy pellets had the lowest ruminal escape protein followed by sun-cured pellets and cubes, respectively, suggesting that the sun-cured pellets and cubes could be a better source of escape protein than the dehy pellets.

Kirkpatrick et al. (1984) evaluated the effects of feeding different inclusion levels of dehy alfalfa, replacing equivalent amounts of concentrate, on milk production and composition. No significant differences were found in milk production or yield, although milk fat percentage and 4% FCM were increased by 10.65% and 4.5%, respectively, when 45% dehy alfalfa was fed (Table 8). These results indicate that dehy alfalfa can be included at 45% of the concentrate without causing detrimental effects on milk production and composition.

The Canadian Dehydrators' Association (1991) recommends that lactating dairy cattle receive 3.5 kg daily and dry cows 2.5 kg daily of dehydrated alfalfa pellets, to replace concentrate and supplement forage. Alfalfa cubes can be used as the sole roughage source for all classes of dairy cattle, although adequate tome should be allotted for an adjustment period.

Table 5. Milk production and milk composition of cows fed brome-alfalfa hay rations with dehydrated alfalfa replacing 0, 3, and 6 kg of the daily concentrate allowance[1]

	Dehydrated alfalfa (kg)			
	0	3	6	SE
Production, kg/d				
Total	27.5	26.6	26.0	1.00
4% FCM	23.5	23.3	24.5	0.54
Fat	0.83	0.84	0.94	0.05
Protein	0.85	0.80	0.78	0.03
Total solids	3.25	3.16	3.19	0.07
Composition, %				
Fat	3.13	3.36	3.63	0.22
Protein	3.11[a]	3.03[b]	3.05[b]	0.01
Total solids	11.92	12.08	12.31	0.21

[1] Adapted from Christensen and Cochran 1983.

[a,b] Means in the same row with different superscripts differ ($P < 0.05$).

Table 6. Milk production and milk composition of cows fed oat silage based rations with dehydrated alfalfa replacing 0, 3, and 6 kg of the daily concentrate allowance[1]

	Dehydrated alfalfa (kg)			
	0	3	6	SE
Production, kg/d				
Total	24.1	23.4	24.1	0.31
4% FCM	22.7	22.9	23.4	0.43
Fat	0.87	0.90	0.92	0.03
Protein	0.82	0.82	0.82	0.01
Total solids	3.02	3.00	3.05	0.04
Composition, %				
Fat	3.67	3.88	3.83	0.15
Protein	3.45	3.50	3.38	0.04
Total solids	12.61	12.81	12.64	0.17

[1] Adapted from Christensen and Cochran 1983.

Table 7. Effect of lucerne processing of dry matter and crude protein kinetic parameters and effective degradability[1]

	Pellets			
	Dehydrated	Sun-cured	Cubes	SEM
Dry matter				
Soluble (%DM)	33.02[a]	23.42[c]	27.04[b]	0.35
Degradable (%DM)	50.01	54.91	53.37	1.20
Degradation rate (%/h)	4.30[a]	3.10[b]	3.40[b]	0.25
Effective degradability (%)	56.05[a]	44.26[c]	48.31[b]	0.42
Crude Protein				
Soluble (%DM)	32.32[a]	29.95[b]	26.93[c]	0.60
Degradable (%DM)	64.70	70.51	66.65	1.88
Degradation rate (%/h)	4.00[a]	3.20[b]	3.40[b]	0.13
Effective degradability (%)	61.14[a]	55.64[b]	55.47[b]	0.40

[1] Adapted from Mustafa et al. 1999.

[a,b,c] Means in the same row followed by different letters are different ($P < 0.05$).

Table 8. Milk yield and composition of cows fed different inclusion levels of dehydrated alfalfa[1]

	Portion of concentrate replaced with dehydrated alfalfa (%)				
	0	15	30	45	SE
Production, kg/d					
Total	25.33	24.88	25.29	24.9	0.87
4% FCM	22	21.6	23.5	23	1.9
Fat	0.77	0.78	0.85	0.87	0.042
Protein	0.866	0.844	0.874	0.848	0.029
Total solids	2.92	2.84	3.02	2.96	0.09
Composition, %					
Fat	3.2	3.34	3.48	3.54	0.135
Protein	3.46	3.48	3.44	3.47	0.05
Total solids	11.62	11.72	11.83	11.93	0.18

[1] Adapted from Kirkpatrick et al. 1984.

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FORAGE HAY CROP

ALFALFA (*MEDICAGO SATIVA* L.) HAY

General Description

Alfalfa is the predominant forage legume grown in all of North America. Alfalfa is valued for its exceptional nutritional quality, its relatively high yields, winter hardiness (McMahon et al. 1999), and drought and heat tolerance. It is recommended that alfalfa be seeded with grass to obtain optimum nutritional value and yields. When alfalfa-grass mixtures are seeded, the highest yields are produced when alfalfa is in early bloom and should be cut at this stage. As with most other forages, the nutritional value of alfalfa hay decreases with increasing maturity, whereby crude protein contents decrease and fibre components increase. The crude protein of alfalfa hay is higher than that of cereal hay, although the energy is slightly lower. The ash and fat content of alfalfa hay is similar to that of cereal hays. The regression equations for predicting amino acids for alfalfa hay are illustrated in Table 1 and the nutrient composition and characteristics of alfalfa hay are shown in Table 2.

The feeding value of alfalfa is exceptional, however high intakes of alfalfa can induce bloat in animals. Alfalfa proteins are rapidly degraded in the rumen, which can cause some soluble proteins to be released forming foam that can lead to bloat. Currently, bloat-free varieties of alfalfa have been developed for grazing purposes.

Table 1. Regression equations for predicting amino acid levels in alfalfa hay from crude protein content[1]

Amino acid	Equation	R value
Methionine	%CP X 0.0164 - 0.0182	0.93
Methionine + Cystine	%CP X 0.0295 - 0.0244	0.95
Lysine	%CP X 0.0604 - 0.2084	0.93
Threonine	%CP X 0.0479 - 0.9000	0.95

[1] Degussa Company 1988.

Table 2. Nutrient composition and characteristics of alfalfa hay (100% DM basis)

Nutrient	Average	SD
CP (%DM)[1]	18.91	2.55
RDP (%CP)[2]	82.0	
RUP (%CP)[2]	18.0	
ADFIP (%DM)[2]	2.38	
NDFIP (%DM)[2]	4.25	
SP (%CP)[2]	28.0	
NPN (%SP)[2]	93.0	
ADF %[1]	34.22	4.30
NDF %[2]	49.00	
Lignin (%DM)[3]	12.0	
Cellulose (%DM)[3]	26.0	
Hemicellulose (%DM)[3]	12.0	
A kd (%/hr)[2]	250.0	
B_1 kd (%/hr)[2]	30.0	
B_2 kd (%/hr)[2]	4.5	
TDN %[1]	61.27	3.66
Energy Coefficients (Mcal/kg)[3]		
DE	2.29	
ME	1.87	
NEm	1.12	
NEg	0.36	
NEl	1.15	
Fat (EE) %[3]	1.80	
Ash %[3]	7.80	
Calcium %[1]	1.67	0.34
Phosphorus %[1]	0.22	0.06
Sodium %[2]	0.12	
Magnesium %[2]	0.35	
Copper (mg/kg)[1]	9.03	1.34
Manganese (mg/kg)[1]	59.41	21.85
Iron (mg/kg)[2]	225.00	
Zinc (mg/kg)[1]	21.47	5.75
Selenium (mg/kg)[2]	0.55	

[1] Saskatchewan Feed Test Laboratory, summary of feed analysis 1990.

[2] NRC, Nutrient Requirements for Beef Cattle 1996.

[3] NRC, United States-Canadian Tables of Feed Composition 1982.

Feeding Value

Steacy et al. (1983) evaluated the nutritive value of brome/alfalfa hay cut at 3 stages of maturity. The brome/alfalfa hay was cut at early maturity (alfalfa cut at 10% bloom), mid maturity (alfalfa cut at 50% bloom), and late maturity (alfalfa cut at full bloom to early seed set). With increasing maturity of the hay, the crude protein content decreased and the fibre components increased. The intake was similar for early and mid cut hay, which was numerically higher than late cut hay (11%). The early cut hay tended to be more digestible than mid cut hay and the digestibility of late cut hay was lower with respect to dry matter, organic matter, crude protein, and energy relative to mid or early cut hay. Steacy et al. (1983) went on to evaluate the feeding value of these hays with two levels of concentrate, high and low. The level of concentrate fed did not affect the total dry matter intake of the rations. Animals fed early cut hay with low concentrate levels had higher milk yields than those fed diets containing mid to late cut hay with low concentrate levels. Those animals fed early and mid cut hays with high concentrate tended to have higher yields and milk fat percentage relative to those fed lat cut hay and high concentrate rations, although not significantly different. No other milk characteristics were influenced by the maturity of the hay or concentrate level. This data suggests that the nutritive value of brome/alfalfa hay is greatest when cut when alfalfa is in early bloom.

Bartlett and Ritchie (1979) found that the addition of barley grain to alfalfa hay diets increased the amount of energy in the ration, aiding in increased heat production of wintering calves relative to alfalfa hay diets alone.

Belyea et al. (1989) studied the effects of feeding different particles sizes of alfalfa hay to dairy cattle on forage utilization and cattle performance. It was found that particle size did not significantly affect dry matter intake, fibre digestibility, milk yield, or milk fat percentage of lactating dairy cattle, suggesting that chopping alfalfa forage is not necessary to improve the feeding value of alfalfa hay.

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BARLEY HAY

General Description and Nutrient Composition

Barley crops seeded for forage can be harvested as hay. Similar to other cereal hays, as the maturity of the plant increases, the nutritive value of the hay becomes poorer. Unlike most other cereal hays, the fibre components of barley hay remain similar at all stages of harvest. Barley hay has the highest nutritional value of all cereal hays with the highest crude protein value, lowest fibre components, and increased energy. The nutrient composition and characteristics are shown in Table 1. Although the nutritional value of barley hay is higher than other cereal forages, the yields are below that of oat hay, which may hinder its use. To obtain the highest yields without compromising nutritional value, barley hay should be cut at the dough stage.

Feeding Value

The feeding value of barley hay for ruminant animals approaches that of barley silage. Economides et al. (1995) compared cattle performance when fed either barley hay or barley silage. It was found that milk yield, milk composition, and body weight changes were similar for cattle consuming barley hay diets and barley silage based rations. The authors concluded that silage and hay obtained from barley cut at the same stage of maturity gave similar performance and could be substituted for one another as the roughage component of the total diet.

Table 1. Nutrient composition and characteristics of barley hay (100% DM basis)

Nutrient	Average	SD
CP (%DM)[1]	11.22	3.0
RDP (%CP)[?]		
RUP (%CP)[?]		
ADFIP (%DM)[?]		
NDFIP (%DM)[?]		
SP (%CP)[?]		
NPN (%SP)[?]		
ADF %[1]	37.33	3.25
NDF %[2]	64.1	
Lignin (%DM)[2]	6.77	
Cellulose (%DM)[2]	34.50	
Hemicellulose (%DM)[2]	22.90	
Starch (%)[?]		
A kd (%/hr)[?]		
B_1 kd (%/hr)[?]		
B_2 kd (%/hr)[?]		
TDN %[1]	58.4	3.03
Energy Coefficients (Mcal/kg)[3]		
DE	2.47	
ME	2.04	
NEm	1.21	
NEg	0.51	
NEl	1.25	
Fat (EE) %[3]	2.10	
Ash %[3]	7.60	
Calcium %[1]	0.39	0.14
Phosphorus %[1]	0.26	0.05
Sodium %[3]	0.14	
Magnesium %[3]	0.18	
Copper (mg/kg)[3]	24.00	
Manganese (mg/kg)[3]	27.00	
Iron (mg/kg)[3]	101.00	
Zinc (mg/kg)[3]	48.00	
Selenium (mg/kg)[3]	0.16	

[1] Saskatchewan Feed Test Laboratory, summary of feed analysis 1990.

[2] Stephanyshyn-Cote 1994.

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OAT HAY

General Description and Nutrient Composition

Oat crops can be harvested for use as forage hay and is among one of the nutritionally highest cereal crops grown. Oat forage yields are the highest among all the cereal crops grown and is best seeded in mid to late May. Oat hay is one of the most common cereal hays fed in western Canada, due to its high yields and relatively high nutritional quality.The quality of oat hay declines with increasing maturity, as the crude protein content decreases and the fibre components increase. The crude protein content of oat hay is similar to that of wheat hay, although oat hay has a higher level of energy. The fat and mineral contents of oat hay are comparable to that of other cereal hays. The nutritional composition and characteristics of oat hay are illustrated in Table 1. Oat forage should be cut at the dough stage to provide optimum forage quality with fair yields. Oat crops seeded for forage can also be utilized as pasture and regrowth is possible if grazed early in the season. The inclusion level of oat hay in ruminant rations is dependent upon the nutritional value of the hay.

Feeding Value

Erickson et al. (1977) evaluated the nutritional value of oat hay harvested at several stages of maturity. It was found that forage yields were maximized when harvested at the milk stage or later. However, with advancing maturity the crude protein and ash contents declined, although fibre contents were not affected by growth stage. Erickson et al. (1977) concluded that oats be harvested at the late milk to early dough stage to obtain optimum nutritive value and forage yield.

Different processing methods to improve the nutritional value of oat hay have been practiced; however, not all practices have been successful. Prado et al. evaluated oat hay particle size (1995) and it was found that the size of particles did not influence the voluntary intake of oat hay by sheep. The dry matter, crude protein, organic matter, and ether extract digestibilities were similar between both particle sizes. However, fibre digestibility was improved when rations contained longer particles (10mm) compared to a shorter particle size (5mm). Roa and Thakur (1993) found that chaffing or grinding oat hay increased the palatability, intake, and TDN in cattle. Singhal et al. (1992) evaluated the efficacy of feeding calves diets of chopped or unchopped oat hay as the sole feed, with the addition of a mineral mix. Dry matter intake and nutrient digestibility remained the same among calves fed both rations, suggesting that chopping does not improve the nutritional value of oat hay and is not needed.

Bhargava and Ranjhan (1976) found that sheep fed oat hay based diets gained significantly more weight and produced significantly more wool than those consuming a wheat straw based ration, indicating that oat hay is of better nutritive value than wheat straw.

Table 1. Nutrient composition and characteristics of oat hay (100% DM basis)

Nutrient	Average	SD
CP (%DM)[1]	10.83	3.04
RDP (%CP)[2]	68.0	
RUP (%CP)[2]	32.0	
ADFIP (%DM)[2]	0.95	
NDFIP (%DM)[2]	2.85	
SP (%CP)[2]	30.0	
NPN (%SP)[2]	93.0	
ADF %[1]	37.59	3.0
NDF %[2]	63.00	
Lignin (%DM)[2]	5.72	
Cellulose (%DM)[?]		
Hemicellulose (%DM)[3]	26.0	
Starch (%)[?]		
A kd (%/hr)[2]	250.0	
B_1 kd (%/hr)[2]	30.0	
B_2 kd (%/hr)[2]	4.0	
TDN %[1]	57.0	3.1
Energy Coefficients (Mcal/kg)[3]		
DE	2.69	
ME	2.27	
NEm	1.33	
NEg	0.69	
NEl	1.38	
Fat (EE) %[3]	2.60	
Ash %[3]	7.60	
Calcium %[1]	0.37	0.13
Phosphorus %[1]	0.22	0.06
Sodium %[2]	0.18	
Magnesium %[2]	0.29	
Copper (mg/kg)[1]	3.99	0.64
Manganese (mg/kg)[1]	60.10	7.39
Iron (mg/kg)[2]	406.00	
Zinc (mg/kg)[1]	23.29	1.22
Selenium (mg/kg)[2]	0.00	

[1] Saskatchewan Feed Test Laboratory, summary of feed analysis 1990.

[2] NRC, Nutrient Requirements for Beef Cattle 1996.

[3] NRC, United States-Canadian Tables of Feed Composition 1982.

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RYE HAY

General Description

Fall rye can be grown for harvesting as hay or it can be successfully grazed. It is extremely drought and cold tolerant and it is well adapted for growth on most Saskatchewan soils. The nutritional quality of rye forage tends to decrease with increasing maturity. Typically rye hay yields are comparable to those of wheat and barley hay, but lower than oat hay yields. However, there is considerable variability in yields of fall rye hay depending on the maturity at harvest and the environmental conditions leading up to cutting.

Chemical Composition and Feeding Value

Stephanyshyn-Cote (1994) evaluated the chemical composition of two fall rye hays in comparison to barley hay at various stages of maturity. It was found that for all forages as the maturity of the plant increased the crude protein and ash content declined significantly between heading and the firm dough stage. Similarly, the ADF and NDF content of all forages decreased as the maturity increased from heading to the firm-dough stage. Fall rye hays had a higher ADF and NDF content relative to barley hay, but ADF and NDF content remained similar between the two species of fall rye. The lignin content of the forages increased through early maturity then declined through late maturity. As the maturity of the plants increased the cellulose content decreased and the starch deposition increased. The chemical composition and characteristics of rye hay are illustrated in Table 1. These results indicate that maturity at cutting plays an extreme factor in the nutritive value of fall rye and barley hays.

Stephanyshyn-Cote (1994) also determined the IVOMD of the three different forages at differing levels of maturity (Table 2). The IVOMD decreased significantly up to the early-milk stage, whereby it was maintained or rose slightly thereafter. The IVOMD was similar between the two fall rye hays, which were significantly lower than the organic matter digestibility of barley hay.

Table 1. Nutrient composition and characteristics of rye hay (100% DM basis)

Nutrient	Average	SD
CP (%DM)[1]	8.67	2.69
RDP (%CP)[?]		
RUP (%CP)[?]		
ADFIP (%DM)[?]		
NDFIP (%DM)[?]		
SP (%CP)[?]		
NPN (%SP)[?]		
ADF %[2]	46.6	
NDF %[2]	73.8	
Lignin (%DM)[2]	6.78	
Cellulose (%DM)[2]	39.80	
Hemicellulose (%DM)[2]	27.3	
Starch (%)[?]		
A kd (%/hr)[?]		
B_1 kd (%/hr)[?]		
B_2 kd (%/hr)[?]		
TDN %[1]	53.8	3.56
Energy Coefficients (Mcal/kg)[3]		
DE		
ME		
NEm		
NEg		
NEl		
Fat (EE) %[?]		
Ash %[2]	6.36	
Calcium %[1]	0.30	0.10
Phosphorus %[1]	0.18	0.05
Sodium %[?]		
Magnesium %[?]		
Copper (mg/kg)[?]		
Manganese (mg/kg)[?]		
Iron (mg/kg)[?]		
Zinc (mg/kg)[?]		
Selenium (mg/kg)[?]		

[1] Saskatchewan Feed Test Laboratory, summary of feed analysis 1990.

[2] Stephanyshyn-Cote 1994.

Table 2. The in vitro organic matter digestibility (%) of fall rye and barley hays cut at different stages of maturity (100% DM basis)[1]

	Heading	Flowering	Early milk	Mid-milk	Firm dough	SEM[2]
Fall rye						
Musketeer	49.3 *b A*	44.1 *a B*	39.7 *c B*	40.9 *b B*	44.0 *b B*	1.18
Prima	47.1 *b A*	46.1 *a A*	41.2 *b B*	44.5 b *AB*	44.7 *b A*	0.79
Bonanza Barley	60.3 *a A*		48.5 *a C*	51.5 *a BC*	54.7 *a AB*	1.74
SEM	2.59	0.84	1.66	2.04	2.24	

[1] Adapted from Stephanyshyn-Cote 1994.

[2] SEM = Standard error of the mean.

a-c Figures in the same column followed by different letters are significantly different ($P < 0.05$).

A-C Figures in the same row followed by different letters are significantly different ($P < 0.05$).

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TRITICALE HAY

General Description

Triticale, as with most other cereal crops, can be cut for hay as feed for ruminant animals. Variety and cutting dates have an impact on the nutritive value of triticale forage. Triticale should be cut at an early maturity, such as the milk stage, to obtain hay with optimum quality and improved feeding value.

Nutritive and Feeding Value

Feron et al. (1990) compared the nutritive value of triticale forage seeded and harvested at two different dates. It was found that dry matter and organic matter digestibilities were not affected by the seeding date. However, the digestibility of dry matter, organic matter, crude protein, ash, calcium, and phosphorus were higher for forage harvested early (tillering) relative to triticale harvested at a later date (dough stage).

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WHEAT HAY

General Description and Nutrient Composition

Wheat hay, like most other cereal hays, varies in nutrient composition with varying forage maturity. As the maturity of the hay increases, the crude protein, nutrient digestibility and intake of the forage decrease leading to decreased animal performance. The yield of wheat is lower than that of oats and similar to that of rye and triticale. Wheat forage grown in combination with a legumous forage provides a higher nutritive value than wheat hay grown alone, leading to a potential improvement in animal performance. Wheat has a crude protein value similar to oat hay with slightly lower TDN and mineral content. The nutrient composition and characteristics are shown in Table 1. To maximize yields and quality, wheat hay should be harvested at the early dough stage. Wheat grown for forage is most suitable as hay but can be grazed in early spring with regrowth throughout the summer.

Feeding Value

Belyea et al. (1978) evaluated the nutritive value of wheat forage cut at different stages of maturity. It was found that the optimum time to cut was at the boot to early head stage, where crude protein, TDN, and NEl were maximized. The authors suggested that wheat hay cut at this stage had a feeding value approaching that of corn silage and could be used to substitute corn silage in dairy rations.

Table 1. Nutrient composition and characteristics of wheat hay (100% DM basis)

Nutrient	Average	SD
CP (%DM)[1]	10.58	2.64
RDP (%CP)[?]		
RUP (%CP)[?]		
ADFIP (%DM)[2]	0.8	
NDFIP (%DM)[2]	1.1	
SP (%CP)[?]		
NPN (%SP)[?]		
ADF %[1]	41.36	3.42
NDF %[2]	61.10	
Lignin (%DM)[3]	7.00	
Cellulose (%DM)[?]		
Starch (%)[?]		
A kd (%/hr)[?]		
B_1 kd (%/hr)[?]		
B_2 kd (%/hr)[?]		
TDN %[1]	54.73	3.56
Energy Coefficients (Mcal/kg)[3]		
DE	2.56	
ME	2.13	
NEm	1.26	
NEg	0.58	
NEl	1.30	
Fat (EE) %[3]	2.20	
Ash %[3]	7.10	
Calcium %[1]	0.22	0.06
Phosphorus %[1]	0.20	0.05
Sodium %[2]	0.06	
Magnesium %[2]	0.13	
Copper (mg/kg)[1]	7.42	
Manganese (mg/kg)[2]	62.00	
Iron (mg/kg)[2]	319.00	
Zinc (mg/kg)[2]	25.00	
Selenium (mg/kg)[?]		

[1] Saskatchewan Feed Test Laboratory, summary of feed analysis 1990.

[2] NRC, Nutrient Requirements for Dairy Cattle 2001.

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GRASS AND GRASS HAYS

CRESTED WHEATGRASS (*AGROPYRON DESERTORUM* L.)

General Description

Crested wheatgrass, a bunch-type plant, is particularly suited to the brown soils of western Canada and is able to withstand extreme periods of cold and drought. However it does not yield well on saline soils and is not tolerant of prolonged flooding (Knowles and Buglass 1980). Crested wheatgrass is used primarily for pasture use with the most extensive grazing during the early spring period. Crested wheatgrass yields approximately twice the amount of native grasses and can be stocked three times as heavily (Lodge et al. 1974). The nutritive value and palatability of crested wheatgrass decline as the forage matures (Lodge et al. 1974). Crested wheatgrass can be used for hay and it is recommended that it be cut at mid to late June, so as to obtain the optimum yield and quality of the forage. The nutrient composition and characteristics of crested wheat grass are shown in Table 1.

Feeding Value

Jones et al. (1994) evaluated cow preference of 4 wheatgrass taxa; crested wheatgrass, thickspike wheatgrass, Snake River wheatgrass, and blue bunch wheatgrass. The cattle were grazed in spring and the trial lasted over a two-year period. It was found that the number of bites for crested wheatgrass in the first year was three times that of thickspike wheatgrass, which had the next highest number of bites. Similarly in the second year, animals fed crested wheatgrass took twice as many bites as those fed the other 3 forages. This data indicates that when cattle had a choice they preferred crested wheatgrass to the native wheatgrasses, which led the authors to recommend that crested wheatgrass be used for spring grazing where it is adapted.

Adams et al. (1993) evaluated the influence of feeding native or seeded pasture to high and low milk producing beef cows on milk production. The seeded pasture contained crested wheatgrass, alfalfa, and Russian wild ryegrass and the native pastures contained a variety of species. It was found that cows produced similar milk yields when fed either native or seeded pasture, indicating that the nutritive value was comparable between native and seeded range.

Table 1. Nutrient composition and characteristics of crested wheatgrass (100% DM basis)

Nutrient	Average	SD
CP (%DM)[1]	10.64	6.88
RDP (%CP)[2]	67.0	
RUP (%CP)[2]	33.0	
ADFIP (%DM)[2]	0.55	
NDFIP (%DM)[2]	2.79	
SP (%CP)[2]	25.0	
NPN (%SP)[2]	96.0	
ADF %[1]	40.29	5.11
NDF %[1]	65.00	
Lignin (%DM)[2]	6.00	
Cellulose (%DM)		
Starch (%)		
A kd (%/hr)[2]	250.0	
B_1 kd (%/hr)[2]	30.0	
B_2 kd (%/hr)[2]	3.0	
TDN %[1]	55.0	5.21
Energy Coefficients (Mcal/kg)[3]		
DE	2.47	
ME	2.03	
NEm	1.18	
NEg	0.61	
NEl	1.25	
Fat (EE) %[2]	2.30	
Ash %[2]	9.00	
Calcium %[1]	0.39	0.04
Phosphorus %[1]	0.18	0.10
Sodium %		
Magnesium %		
Copper (mg/kg)		
Manganese (mg/kg)		
Iron (mg/kg)		
Zinc (mg/kg)		
Selenium (mg/kg)		

[1] Saskatchewan Feed Test Laboratory, summary of feed analysis 1990.

[2] NRC, Nutrient Requirements of Beef Cattle 1996.

[3] Christensen and Steacy 1985.

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MEADOW BROMEGRASS (*BROMUS RIPARIUS*)

General Description

Meadow bromegrass is an introduced forage species that is essentially used for pasture but may be harvested for use as hay. Meadow bromegrass is a recent introduction in western Canada (Knowles et al. 1993) and little information is available on the sustainability of this forage in semi-arid regions. Holt and Jefferson (1999) found that meadow bromegrass, averaged over a five year period, had similar yields to that of Russian wildrye, Altai wildrye, and intermediate wheatgrass when grown with alfalfa. Annual inconsistencies in forage yield occurred as a result of precipitation, suggesting that precipitation plays an important role in determining the yield of grass-alfalfa forage. Pasture yields can be affected by such things as grazing pressure, grazing systems, fertilizers, forage species, and environmental conditions (Popp et al. 1999). Meadow bromegrass is very similar in nutritive value to that of crested wheatgrass. It has a slightly lower crude protein content but is similar in energy, fibre, and ash content to that of crested wheatgrass. The nutrient content and characteristics of meadow bromegrass are illustrated in Table 1.

Feeding Value

Horney et al. (1992) compared the feeding value of tall fescue straw supplemented with alfalfa hay to that of tall fescue straw supplemented with a good quality medow hay. It was found that when steers were fed these rations the dry matter intake of straw supplemented with meadow hay was 12% higher than straw supplemented with alfalfa hay. The average daily gain of steers was higher when supplemented with meadow hay. This study lead the authors to conclude that a high quality meadow hay is more efficient in supplementing a low quality forage than alfalfa hay.

Holt and Jefferson (1999) found that average daily gain of steers fed meadow bromegrass was comparable to the gain of steers fed Russian wildrye, Altai wildrye, and intermediate wheatgrass in combination with alfalfa. Worrell et al. (1986) found that cattle intake of digestible organic matter decreased as the maturity of meadow bromegrass increased and gains were highest when cattle were fed meadow brome of early maturity.

Table 1. Nutrient composition and characteristics of meadow bromegrass (100% DM basis)

Nutrient	Average	SD
CP (%DM)[1]	6.95	1.202
RDP (%CP)		
RUP (%CP)		
ADFIP (%DM)		
NDFIP (%DM)		
SP (%CP)		
NPN (%SP)		
ADF %[1]	39.7	0.566
NDF %		
Lignin (%DM)		
Cellulose (%DM)		
Starch (%)		
A kd (%/hr)		
B_1 kd (%/hr)		
B_2 kd (%/hr)		
TDN%[2]		
Energy Coefficients (Mcal/kg)[2]		
DE	58.3	
ME		
NEm	2.61	
NEg	2.14	
NEl	1.28	
Fat (EE) %	0.71	
Ash %	1.33	
Calcium %[1]		
Phosphorus %[1]		
Sodium %	0.285	0.078
Magnesium %	0.230	0.099
Copper (mg/kg)		
Manganese (mg/kg)		
Iron (mg/kg)		
Zinc (mg/kg)		
Selenium (mg/kg)		

[1] Hayes et al. 1990.

[2] Christensen and Steacy 1985.

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SAINFOIN (*ONOBRYCHIS VICIIFOLIA*)

General Description

Sainfoin is a perennial legume that grows well on soils where alfalfa grows well, although the yields can be as much as 10 to 15% lower than that of alfalfa (Fraser and Fraser 1994). When cut at the same stage of maturity the protein content of sainfoin is lower than that of alfalfa but sainfoin is higher in TDN relative to alfalfa. The nutrient composition and characteristics of sainfoin are presented in Table 1. Sainfoin can be grazed readily due to its bloat-free properties. These are attributed to the increased presence of condensed tannins that reduce the amount of soluble protein concentration in the rumen, which limit the production of foam that is characteristically associated with the incidence of bloat (Jones et al. 1973, as quoted by McMahon et al. 1999). Sainfoin produces very early and is highly palatable, but it does not regrow well as pasture or hay.

Feeding Value

In 1999, McMahon and colleagues studied the effects of including sainfoin in alfalfa based steer rations to determine the influence on bloat. Alfalfa was cut at the vegetative to early-bloom stage and sainfoin at early- to full-bloom. It was found that replacing alfalfa with an equivalent amount of sainfoin reduced the incidence of bloat in 3 of 4 years in this trial. When sainfoin was included in the diet, bloat was reduced by as much as 93% and varied with the form of sainfoin fed and the inclusion level.

Table 1. Nutrient composition and characteristics of sainfoin (100% DM basis)

Nutrient	Average
CP (%DM)[1]	15.40
RDP (%CP)	
RUP (%CP)	
ADFIP (%DM)	
NDFIP (%DM)	
SP (%CP)	
NPN (%SP)	
ADF %[1]	37.0
NDF %	
Lignin (%DM)	
Cellulose (%DM)	
Starch (%)	
A kd (%/hr)	
B_1 kd (%/hr)	
B_2 kd (%/hr)	
TDN %[2]	58.4
Energy Coefficients (Mcal/kg)[1]	
DE	2.78
ME	2.28
NEm	1.40
NEg	0.83
NEl	1.42
Fat (EE) %	
Ash %	
Calcium %	
Phosphorus %	
Sodium %	
Magnesium %	
Copper (mg/kg)	
Manganese (mg/kg)	
Iron (mg/kg)	
Zinc (mg/kg)	
Selenium (mg/kg)	

[1] Christensen and Steacy 1985.

[2] Hayes et al. 1990.

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NATIVE HAY

General Description

Native hay provides an excellent source of supplemental forage for livestock and can be used for hay or grazing. There are many species of native hay such as timothy, tall fescue, blue gramma, and reed canarygrass, to name a few. Native grasses provide a dependable forage source with low maintenance as pesticides, herbicides, and fertilizers are not needed. Native grasses are more tolerable of environmental changes relative to tame species. When used for hay the harvesting date is crucial to the nutritive value, yield, and regrowth of the forage. As the plants mature, crude protein and energy levels decline. However, if cut too early the grass may not have adequate amount of time to replenish carbohydrate reserves before frost. Generally, native hay should be cut around mid-July and if it cannot be cut by August it is best not to cut at all and graze the area after frost. Native hay has a lower crude protein content than tame hay but is typically higher in energy. Native grasses provide lush pasture for grazing during the summer months and allows for increasing gains. The nutrient composition and characteristics of native hay are illustrated in Table 1.

Table 1. Nutrient composition and characteristics of native hay (100% DM basis)

Nutrient	Average
CP (%DM)[1]	7.01
ADF %[1]	34.43
TDN %[1]	60.00
Energy Coefficients (Mcal/kg)[2]	
DE	2.65
ME	2.22
NEm	1.36
NEg	0.78
NEl	1.35
Calcium %[1]	0.42
Phosphorus %[1]	0.18
Copper (mg/kg)[1]	4.60
Manganese (mg/kg)[1]	73.50
Zinc (mg/kg)[1]	19.62

[1] Saskatchewan Feed Test Laboratory 1990.

[2] NRC, Energy Prediction Equations, Nutrient Requirements of Dairy Cattle 2001.

Feeding Value

The feeding value of native hay varies depending upon the type of grass and the stage in which it is cut. For the most part, native hays are very palatable for all classes of livestock and support good gains.

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BROMEGRASS HAY

General Description

Bromegrass is an introduced, cool season, perennial species grown on heavier soils of western Canada. Bromegrass needs relatively high moisture conditions to reach peak performance and does well on heavier soils that retain moisture, such as brown and dark brown soils. Optimum yields and forage quality can be obtained when brome hay is grown in combination with alfalfa compared to being seeded alone. The nutritional quality of brome hay is similar to that of cereal hays and greater than other introduced or native grasses. The nutritional value of brome hay is shown in Table 1. Bromegrass is most suitable as a hay crop but can be used for pasture.

Feeding Value

Steacy et al. (1983) evaluated the nutritive value of brome/alfalfa hay cut at 3 stages of maturity. The brome/alfalfa hay was cut at early maturity (alfalfa cut at 10% bloom), mid maturity (alfalfa cut at 50% bloom), and late maturity (alfalfa cut at full bloom to early seed set). With increasing maturity of the hay, the crude protein content decreased and the fibre components increased. The intake was similar for early and mid cut hay, which was numerically higher than late cut hay (11%). The early cut hay tended to be more digestible than mid cut hay and the digestibility of late cut hay was lower with respect to dry matter, organic matter, crude protein, and energy relative to mid or early cut hay. Steacy et al. (1983) went on to evaluate the feeding value of these hays with two levels of concentrate, high and low. The level of concentrate fed did not affect the total dry matter intake of the rations. Animals fed early cut hay with low concentrate levels had higher milk yields than those fed diets containing mid to late cut hay with low concentrate levels. Those animals fed early and mid cut hays with high concentrate tended to have higher yields and milk fat percentage relative to those fed lat cut hay and high concentrate rations, although not significantly different. No other milk characteristics were influenced by the maturity of the hay or concentrate level. This data suggests that the nutritive value of brome/alfalfa hay is greatest when cut when alfalfa is in early bloom.

Table 1. Nutrient composition and characteristics of brome hay (100% DM basis)

Nutrient	Average	SD
CP (%DM)[1]	11.08	2.61
RDP (%CP)[2]	79.0	
RUP (%CP)[2]	21.0	
ADFIP (%DM)[2]	0.94	
NDFIP (%DM)[2]	4.46	
SP (%CP)[2]	25.0	
NPN (%SP)[2]	96.0	
ADF %[1]	39.19	3.52
NDF %[1]	57.7	
Lignin (%DM)[2]	3.50	
Cellulose (%DM)		
Starch (%)		
A kd (%/hr)[2]	250.0	
B_1 kd (%/hr)[2]	30.0	
B_2 kd (%/hr)[2]	3.0	
TDN %[1]	55.7	3.33
Energy Coefficients (Mcal/kg)[3]		
DE	2.30	
ME	1.89	
NEm	1.05	
NEg	0.49	
NEl	1.16	
Fat (EE) %[2]	2.20	
Ash %[2]	10.9	
Calcium %[1]	0.58	0.22
Phosphorus %[1]	0.17	0.03
Sodium %[2]	0.01	
Magnesium %[2]	0.10	
Copper (mg/kg)[1]	9.89	1.92
Manganese (mg/kg)[2]	40.00	
Iron (mg/kg)[2]	91.00	
Zinc (mg/kg)[1]	22.98	3.15
Selenium (mg/kg)[2]	0.00	

[1] Saskatchewan Feed Test Laboratory, summary of feed analysis 1990.

[2] NRC, Nutrient Requirements for Beef Cattle 1996.

[3] Christensen and Steacy 1985.

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SLOUGH HAY

General Description

Slough hay can provide the forage requirements of sheep, beef, and dairy cattle, if supplemented adequately. Typically slough hay has a feeding value slightly higher than that of cereal straws and can approach that of brome hay. Supplementation with grain to meet energy and protein requirements of wintering beef cattle is necessary as the coarse material is less digestible and will lower these levels. In an extreme feed shortage, slough hay can be used as the sole forage source in ruminant rations, but is best complemented with a processed alfalfa product. Slough hay should be harvested prior to frost to maintain optimum nutritive value. The nutrient composition and characteristics of slough hay are illustrated in Table 1.

Table 1. Nutrient composition and characteristics of slough hay (100% DM basis)

Nutrient	Average	SD
CP (%DM)[1]	8.83	1.63
ADF %[1]	41.64	1.86
TDN %[1]	53.74	1.73
Energy Coefficients (Mcal/kg)[2]		
DE	2.22	
ME	1.82	
NEm	0.97	
NEg	0.42	
NEl	1.12	
Calcium %[1]	0.49	0.14
Phosphorus %[1]	0.14	0.03
Copper (mg/kg)[1]	5.09	
Manganese (mg/kg)[1]	63.65	
Zinc (mg/kg)[1]	34.50	

[1] Saskatchewan Feed Test Laboratory 1990.

[2] Christensen and Steacy 1985.

Feeding Value

In a 1977 study conducted by Anderson and colleagues, the intake and nutrient digestibility of slough hay and dehydrated alfalfa pellets by steers and rams were compared. The intake of slough hay was lower than that of dehydrated pellets by 27 and 53% for steers and rams, respectively. The energy density of both feeds remained similar among species, but was slightly higher for rams. The crude protein digestibility of dehydrated alfalfa pellets was higher than slough hay, although the crude fibre digestibility of slough hay was greater than that of dehydrated alfalfa pellets. The crude fibre of slough hay was digested equally well between both species, however, rams digested the dehydrated pellets more efficiently than did steers. This study suggests that slough hay has a lower feeding value than that of dehydrated alfalfa pellets but is still a viable option for feeding in times of shortage.

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SILAGE

BARLEY (*HORDEUM VULGARE*) SILAGE

General Description

Barley silage is the most commonly used of the cereal forages (Christensen 1991). Whole plant barley silage is made from immature barley plants that are cut and stored in an airtight silo to exclude oxygen and ferment the product to an optimal pH of between 3.8 and 4.2, so as to preserve the quality of the feed. As the barley crop matures, the feeding value changes. The TDN of barley silage changes slightly from early to late dough stages (Christensen 1991). The apparent nutrient digestibilities and nutrient composition of barley silage are shown in Tables 1 and 2. Barley, harvested for the purpose of silage, should be cut when the heads are well filled and the grain is in the mid-dough stage. At this maturity it will contain about 55 to 65 percent moisture, which is the optimal moisture for ensiling. If the crop contains moisture in excess of 65% it should be wilted to reduce the moisture before being chopped and ensiled. Barley crops that are harvested for the purpose of silage can have yields similar to that of corn. A conclusive amount of barley silage to be used in ruminant rations is indeterminate because of nutrient variation due to soil, climate, maturity, and other factors.

Table 1. Apparent nutrient digestibilities of different barley varieties with various treatments[1]

	Apparent Digestibilities, %				
Variety (treatment)	DM	OM	CP	ADF	NDF
Scout (hulless)	58.2	58.6	68.3	42.3	47.3
Hearland	56.4	57.6	57.4	37.7	39.2
Hearland (bagged)	60.2	61.5	63.8	42.8	46.2
Heartland (treated with Cerone)	59.0	59.9	67.5	40.9	44.6
Heartland (treated with Cerone; bagged)	63.8	65.2	67.2	48.7	50.6
Heartland (tower silo)	61.4	62.8	64.6	50.1	55.4

[1] Christensen and Steacy 1985.

Table 2. Nutrient composition and characteristics of barley silage (100% DM basis)

	Barley			
Nutrient	Silage[a]	Silage, headed[b]	Silage[c]	Heartland[d]
CP (%DM)[1]	11.90	12.00	12.68	9.31
RDP (%CP)[2]	86.0			
RUP (%CP)[2]	14.0			
ADFIP (%DM)[2]	0.73	0.9		
NDFIP (%DM)[2]	0.92	1.6		
SP (%CP)[2]	70.0			
NPN (%SP)[2]	100.0			
CF %[3]				26.82
ADF %[1]		34.5	33.52	33.51
NDF %[1]	56.8	56.3		50.78
Lignin (%DM)[2]	3.09	5.6		3.77
Cellulose (%DM)[3]				
Starch (%)[1]				
A kd (%/hr)[2]	300.0			
B_1 kd (%/hr)[2]	50.0			
B_2 kd (%/hr)[2]	10.0			
Energy coefficients (ruminants)				
TDN %	60.0	60.2	62.49	
DE (Mcal/kg)		2.68		2.46
ME (Mcal/kg)	2.17	2.03		2.02
NEm (Mcal/kg)	1.31	1.33		1.17
NEg (Mcal/kg)	0.74	0.76		0.61
NEl (Mcal/kg)		1.24		1.25
Fat (EE) %[1]	2.92	3.50		
Ash %[1]	8.30	7.50		
Calcium %[6]	0.52	0.48	0.47	0.42
Phosphorus %[6]	0.29	0.30	0.32	0.37
Sodium % 3	0.12	0.13		
Magnesium %[6]	0.19	0.18		0.34
Copper (mg/kg)[6]	7.70	7.00	5.40	3.30
Manganese (mg/kg)[6]	44.80	43.00	38.48	21.00
Iron (mg/kg)[6]	375.00	343.00		110.00
Zinc (mg/kg)[6]	24.50	30.00	24.96	20.00
Selenium (mg/kg)[6]	0.15	0.00		

[a] NRC, Nutrient Requirements for Beef Cattle 1996.

[b] NRC, Nutrient Requirements for Dairy Cattle 2001.

[c] Saskatchewan Feed Test Laboratory, summary of feed analysis 1990.

[d] Christensen and Steacy 1985.

Feeding value

Research conducted at the University of Saskatchewan by Christensen (1991), has shown that feeding barley silage cut at a later stage resulted in higher dry matter intakes, higher body weight gains, and higher milk yields (Table 3) relative to those animals fed barley silage cut at a less mature stage. Christensen (1991) has also observed that barley silage harvested at the stiff dough stage acquired a higher TDN content and a lower level of NDF (Table 4). These results contradict some literature, whereby barley silage cut at an earlier maturity supported higher milk yields and composition.

Khorasani et al. (1993) examined the effects of supplementing different forages on intake, nutrient digestibility, and milk production and composition in lactating dairy cow. The silage used was one of alfalfa, barley, oats, or triticale in combination with concentrate at 50:50 ratio. It was found that the DMI of alfalfa and barley silage were similar and higher than that of oat or triticale silage (Table 5). The type of silage did not affect milk production, 4% FCM, and milk fat percentage (Table 5). Milk lactose percentage was significantly higher in the cows fed barley silage relative to all other dietary treatments. Whole tract digestibilities were higher for barley and alfalfa silage compared to oat and triticale silage in terms of DM, OM, CP, and ADF. Barley silage numerically had the highest NDF digestitbilty compared to all other dietary treatments. The authors suggested that the higher digestibilities of alfalfa and barley may be reflective of the higher DMI and lower ruminal fill of these feeds.

Enzyme treatment of barley silage has been examined. In 1995, Beauchemin et al. studied the effects of adding fibrolytic enzymes to forage, particularly barley, on fiber digestion and growth rate of steers. It was found that the addition of enzyme to barley silage had minor positive effects, but did not significantly aid in increasing fiber digestibility or growth of steers.

Table 3. Effect of barley variety and stage of maturity on milk yield and composition[1]

	Heartland		Virden	
	Early	Late	Early	Late
Milk yield, kg/d				
Actual	26.4	28.4	26.6	28.9
3.5 % FCM	27.7	28.5	28.1	30.0
Milk composition, %				
Fat	3.94	3.55	3.90	3.76
Protein	3.27	3.36	3.25	3.30

[1] Adapted from Christensen 1991.

Table 4. Nutrient composition and feed intake of barely silage of different varieties harvested at different stages of maturity (100% DM basis)[1]

	DM %	CP %	ADF %	NDF %	TDN %	Intake (%BW)
Harrington						
Flowering	31	13.5	35	59	58	1.6
Stiff dough	35	11.7	30	50	60	1.8
Virden						
Flowering	34	11.8	37	59	61	1.7
Stiff dough	35	10.6	29	46	63	2.0
Heartland						
Flowering	39	12.5	30	50	64	2.0
Siff dough	36	10.5	24	40	66	2.0

[1] Adapted from Christensen 1991.

Table 5. Least square means of feed intake, milk production, and milk composition for early and mid-lactation cows[1]

	Diet				
	Alfalfa	Barley	Oat	Triticale	SEM
DMI, kg/d	18.9^{a}	18.9^{ab}	17.0^{c}	17.6^{bc}	0.80
Production, kg/d					
Milk	28.0	27.3	26.3	25.2	1.10
4% FCM	25.7	25.0	24.4	24.9	1.47
Fat	0.98	0.95	0.93	0.98	0.07
Protein	0.89	0.87	0.82	0.84	0.05
Lactose	1.13	1.31	1.26	1.20	0.07
Milk composition, %					
Fat	3.60	3.64	3.59	3.90	0.20
Protein	3.22^{ab}	3.27^{ab}	3.15^{b}	3.35^{a}	0.09
Lactose	4.70^{b}	4.92^{a}	4.79^{b}	4.71^{b}	0.12

[1] Adapted from Khorasani et al. 1993.

$^{a-c}$ Means in a row with different superscripts are different ($P < 0.05$).

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CORN (*ZEA MAYS*) SILAGE

General Description

Whole plant corn silage is a high yielding energy forage, preserved by anaerobic fermentation in a silo. As with most other cereal silages, the maturity at harvest influences the nutrient composition and digestibility of the ensiled product. Corn silage should be harvested when the milk line is between one quarter and two-thirds the way down the kernel, or approximately 72 and 65% moisture, respectively, so as to provide an optimum forage. Corn is not grown extensively in Saskatchewan due to lower temperatures, hence not enough corn heat units, however it is grown throughout southern Alberta and Manitoba with relatively high yields. Corn silage can be used as the only forage source in ruminant rations, although forage quality will determine the specific utilizable amount. The nutrient composition and characteristics of corn silage are illustrated in Table 1.

Feeding Value

Harvesting whole-plant corn (WPC) at different stages of maturity impacts the nutritional composition and feeding value of the feed for forage. Harvesting immature WPC, fiber concentrations are high, which lowers the energy level of the feed (Hunt et al. 1989, as quoted by Bal et al. 1997). Similarly, the energy density of WPC is lowered when harvested at a mature stage due to the lower digestibility of the feed (Wiersma et al. 1993, as quoted by Bal et al. 1997).

In 1997, Bal et al. studied the effect of harvesting WPC at four stages of maturity for use as silage in the diets of dairy cows on DMI, total tract digestibility, and milk production and composition. The WPC was harvested at early dent (ED), quarter milkline (1/4 ML), 2/3 milkline, and black layer (BL) stages. Dry matter intake remained the same among all treatments (Table 2). Milk production was highest for cows fed the 2/3 ML silage and lowest for those fed the ED silage, both of which did not differ significantly from the milk production of 1/3 ML or BL fed cows. Milk protein yield was highest for cows fed 2/3 ML silage relative to all other dietary treatments. Milk fat yield and milk composition were not altered by maturity differences of WPC silage. As the maturity of corn increased, the digestibility of DM, OM, CP, ADF, and starch all decreased (data not shown). From the results the authors concluded that the optimum maturity stage for harvest of WPC for silage is at the 2/3 ML stage.

Table 1. Nutrient composition and characteristics of corn silage (100% DM basis)

	Corn Silage				
Nutrient	Immature[a]	Normal[a]	Mature[a]	Average[b]	SD
CP (%DM)[1]	9.70	8.80	8.50	9.82	2.33
RDP (%CP)[2]					
RUP (%CP)[2]					
ADFIP (%DM)[2]	0.9	0.8	0.9		
NDFIP (%DM)[2]	1.4	1.3	1.3		
SP (%CP)[2]					
NPN (%SP)[2]					
CF %[3]					
ADF %[1]	34.1	28.1	27.5	30.74	2.45
NDF %[1]	54.1	45	44.5		
Lignin (%DM)[2]	3.5	2.6	3.1		
Cellulose (%DM)[3]					
Starch (%)[1]					
NFC[4]					
A kd (%/hr)[2]					
B_1 kd (%/hr)[2]					
B_2 kd (%/hr)[2]					
TDN% (ruminants)	65.6	68.8	65.4	65.12	2.47
Energy coefficients (Mcal/kg)					
DE	2.87	2.99	2.84		
ME	2.21	2.33	2.19		
NEm	1.48	1.57	1.46		
NEg	0.89	0.97	0.87		
NEl	1.36	1.45	1.35		
Fat (EE) %	2.50	3.20	3.2		
Ash %	4.80	4.30	4.00		
Calcium %	0.29	0.28	0.26	0.33	0.03
Phosphorus %	0.24	0.26	0.25	0.20	0.03
Sodium %	0.01	0.01	0.01		
Magnesium %	0.19	0.17	0.16		
Copper (mg/kg)	6.00	6.00	6.00	4.27	
Manganese (mg/kg)	46.00	36.00	36.00	48.18	
Iron (mg/kg)	157.00	104.00	92.00		
Zinc (mg/kg)	29.00	24.00	23.00	17.47	
Selenium (mg/kg)	0.04	0.04	0.04		

[a] NRC, Nutrient Requirements for Dairy Cattle 2001.

[b] Saskatchewan Feed Test Laboratory 1990.

Dhiman and Satter (1997) evaluated the effects of feeding different inclusion levels of corn silage (CS) in combination with alfalfa silage (AS) in dairy cow rations on milk yield and composition. Cows were randomly assigned to three diets containing 50:50 forage to concentrate with three different combinations of forage consisting of 100% AS, two-thirds AS and one-third CS (1/3 CS), and one-third AS and two-thirds CS (2/3 CS). Dry matter intake was similar among all treatments, although it was noted that animal fed 1/3 CS had the highest intake (Table 3). The crude protein intake decreased as the level of CS increased in the ration, which was expected as these diets contained less crude protein than alfalfa silage. No significant differences were found in terms of other milk characteristics, however cows fed the 1/3 CS diet yielded slightly more milk and 3.5% FCM than did cows fed AS or 2/3 CS. The results led the authors to suggest that feeding 1/3 CS, in combination with AS, as the forage source gives a slight advantage over feding AS alone as the single forage source.

In 1977, the Animal and Poultry Science department of the University of Saskatchewan conducted a study to evaluate the nutritive value of corn silage compared to cereal silage in finishing steer rations. Six treatments were fed to 120 animals housed in groups of 10 with two replicate pens for each treatment. The diets were as follows: cereal silage plus 1 kg of concentrate, corn silage plus 1 kg of concentrate, cereal silage plus 5 kg of concentrate, corn silage plus 5 kg of concentrate, a finishing ration containing 10% roughage, and a finishing ration containing 30% roughage. It was found that animals fed both roughage diets showed greater gains than all silage rations, although the 10% roughage ration gave significantly higher gains than the 30% roughage diet (Table 4). The silage diets supplemented with 5 kg of concentrate produced significantly greater gains than rations supplemented with 1 kg of concentrate. Steers fed corn silage, irrelevant of amount of concentrate fed, had higher average daily gains than those fed cereal silage. As seen in Table 3, animals fed silage plus 1 kg of concentrate took significantly longer to reach desired market weight. Results of digestibility trials revealed that corn silage dry matter had significantly greater nutrient digestibilities than wheat silage or alfalfa-brome hay. Digestibility trials were conducted on all six dietary treatments and it was found that the 10% roughage diet had the highest digestibility coefficients relative to all other rations (results not shown).

Table 2. Effect of corn maturity for use as silage in the diets of dairy cows on DMI, BW, and milk and milk components[1]

	Stage of Maturity[2]				
Item	ED	1/4 ML	2/3 ML	BL	SEM
DMI, kg/d	25.5	25.7	25.7	25.6	0.40
Production, kg/d					
Milk	32.4[b]	32.6[ab]	33.4[a]	32.7[ab]	0.40
4% FCM	30.5	30.1	30.5	30.4	0.50
Milk fat	1.17	1.14	1.14	1.15	0.02
Milk protein	1.12[d]	1.12[d]	1.17[c]	1.13[d]	0.01
Composition, %					
Milk fat	3.60	3.54	3.43	3.52	0.05
Milk protein	3.49	3.48	3.50	3.48	0.02

[1] Adapted from Bal et al. 1997.

[2] Silages are designated by stage of maturity of whole-plant corn at harvest: ED = early dent, 1/4 ML = quarter millkline, 2/3 ML = two-thirds milkline, and BL = black layer.

[a,b] Means in the same row with different superscripts differ ($P < 0.07$).

[c,d] Means in the same row with different superscripts differ ($P < 0.05$).

Table 3. Nutrient intake and lactation performance of cows fed diets containing different proportions of alfalfa silage (AS) and corn silage (CS)[1,2]

	Diet[3]			
Parameter	AS	1/3 CS	2/3 CS	SEM
Cows, n	25	25	24	
DMI, kg/d	20.9	21.4	21.1	0.30
CP intake, kg/d	3.51[a]	3.42[a]	3.19[b]	0.06
Yield, kg/d				
Total	31.1	32.4	31.4	0.50
3.5% FCM	31.0	32.9	31.8	0.50
Fat	1.08	1.17	1.12	0.03
Protein	0.95	1.01	0.99	0.02
Composition, %				
Fat	3.53	3.67	3.65	0.05
Protein	3.08	3.15	3.19	0.03
Lactose	4.86	4.89	4.84	0.02

[1] Adapted from Dhiman and Satter 1997.

[2] Data summarized from week 1 through 36 of lactation.

[3] Diets contained a 50:50 forage to grain ratio. The forage portion of the diet consisted of AS, two-thirds AS and one-third CS (1/3 CS), or one-third AS and two-thirds CS (2/3 CS).

[a,b] Means in the same row with different superscripts differ ($P < 0.05$).

Table 4. The effect of forage amount and type on average daily gain (ADG), feed efficiency, and days on feed[1]

	Start weight (kg)	Final weight (kg)	ADG (kg)	Feed:gain	Days on feed
Cereal silage					
+ 1 kg concentrate	797	981	0.78[a]	11.46	111.3[b]
Corn silage					
+ 1 kg concentrate	801	1016	0.99[b]	9.38	107.8[b]
Cereal silage					
+ 5 kg concentrate	809	1034	1.11[bc]	7.30	93.8[a]
Corn silage					
+ 5 kg concentrate	811	1064	1.22[c]	8.11	95.2[a]
10% roughage					
+ 90% concentrate	774	1086	1.57[e]	5.85	94.8[a]
30% roughage					
+ 70% concentrate	768	1051	1.37[d]	6.88	93.4[a]

[1] Adapted from Saskatchewan Corn Committee report 1979.

[a-e] Means in the same row followed by different superscripts differ ($P < 0.05$).

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OAT (*AVENA SATIVA*) SILAGE

General Description

Oats can be utilized as a grain and forage crop. As a forage crop, it is harvested as hay (greenfeed) and also as silage. The oat plant has a hollow stem and particular care should be taken when packing to exclude air during the ensiling process. Oat silage decreases in TDN content from early to late dough stages, which is in contrast to wheat and barley silage, whereby there is little change in TDN with increasing maturity (Christensen 1991). As with most other cereal silages, the protein content decreases with increasing maturity and in the case of oat silage the digestibility of the protein in also declines (Christensen 1991). The NDF content of oat silage is often higher than that of barley silage and consequently, a lower energy is obtained in oat silage. The voluntary intake of oat silage remains constant or is slightly increased with increasing plant maturity, as is the case in most other cereal silages. The nutrient composition and characteristics of oat silage are presented in Table 1. Oat plants harvested for forage purposes have one of the highest yield potentials compared to many other cereal grain forages. Yields are highest when harvested at the milk stage and decrease if delayed beyond this maturity. The optimal stage of maturity to ensure a balance between yield and quality is at the late milk to early dough stage.

Feeding Value

Christensen and colleagues (1977) evaluated the digestibility and voluntary intake of barley, oat, and wheat silages. It was found that the in vivo digestibility of organic matter was numerically lowest for oats, but did not significantly differ from wheat or barley silages. A similar pattern followed for in vivo digestibility of energy. The in vitro digestibility of organic matter and the digestibility of crude protein did not differ among all species of silages. The voluntary intake of dry matter was highest for oats, although it was not significantly different from that of wheat.

McCartney and Vaage (1994) conducted a study to determine the feeding value of oat, barley, and triticale silage. Results from a heifer performance test showed that animals fed barley silage showed the best performance followed by oat and triticale silage, respectively. However, a sheep digestibility trial found that animals fed oat silage had lower apparent nutrient digestibilities compared to those fed triticale silage.

Schroeder et al. (1979) evaluated the feeding value of high protein oat silage in growing and lactating dairy cattle. The oat silage was harvested at the early dough stage, wilted to 45 to 50% dry matter, and ensiled. Cows were fed one of three diets containing alfalfa-brome hay, Spear oat silage, or Burnett oat silage. It was found that heifers fed Burnett oat silage had a greater DMI and converted feed to gain more efficiently than Spear oat silage, although not significantly (Table 2). Oat silage type did not affect milk yield or milk composition (Table 2), suggesting that the variety of oat silage does not alter milk performance.

Table 1. Nutrient composition and characteristics of oat silage (100% DM basis)

	Oat silage			
Nutrient	Dough[a]	Headed[b]	Average (n=24)[c]	SD
CP (%DM)	12.70	12.90	12.16	2.43
RDP (%CP)	85.0			
RUP (%CP)	15.0			
ADFIP (%DM)	1.27	1.0		
NDFIP (%DM)	3.81	2.1		
SP (%CP)	50.0			
NPN (%SP)	100.0			
CF %				
ADF %		38.9	37.37	5.91
NDF %	58.1	60.6		
Lignin (%DM)	9.34	5.5		
Cellulose (%DM)				
Starch (%)				
A kd (%/hr)	275.0			
B_1 kd (%/hr)	50.0			
B_2 kd (%/hr)	5.0			
TDN %	59.0	56.8	60.37	3.98
Energy Coefficients (Mcal/kg)				
DE		2.54	2.66[d]	0.213
ME	2.13	1.91	2.178[d]	0.176
NEm			1.298[d]	0.119
NEg	1.28	1.23	0.658[d]	0.168
NEl	0.71	0.66	1.36[d]	0.119
Fat (EE) %		1.15		
Ash %	3.12	3.40		
Calcium %	10.10	9.80		
Phosphorus %	0.58	0.52	0.53	0.25
Sodium %	0.31	0.31	0.26	0.05
Magnesium %	0.09	0.24		
Copper (mg/kg)	0.21	0.20		
Manganese (mg/kg)	8.00	9.00		
Iron (mg/kg)	66.30	66.00		
Zinc (mg/kg)	367.00	500.00		
Selenium (mg/kg)	29.80	29.00		

[a] NRC, Nutrient Requirements for Beef Cattle 1996.

[b] NRC, Nutrient Requirements for Dairy Cattle 2001.

[c] Saskatchewan Feed Test Laboratory, summary of feed analysis 1988.

[d] Canadian Feed Information Center 1990.

In 1980, Oltjen and Bolsen compared the feeding value of corn silage, barley, two wheat, and two oat cultivars harvested at the dough stage for ensiling. Table 3 illustrates the results of the performance trial. It was found that animals fed corn and barley silage had similar ADG, which were higher than that of wheat or oat silage. Corn, barley, and wheat silage had significantly higher DMI relative to both types of oat silage. A similar pattern occurred for the feed efficiency, whereby the steers fed oats silage converted feed to gain poorer than those fed corn, barley, or wheat silage. These results suggested that at this stage of maturity, oat silage gave the poorest performance relative to the other cereal silages.

Table 2. Dry matter intake, milk yield, and milk composition of cows fed two types of oat silage[1]

	Silage type		
Item	Spear	Burnett	SEM
DMI, kg/d	20.9	21.3	5.5
Milk yield, kg/d			
Actual	23.2	23.1	4.2
4% FCM	22.4	22.5	0.0
Milk composition, %			
Fat	3.8	3.8	0.1
Protein	3.0	3.0	0.1
Total solids	12.3	12.5	0.2

[1] Adapted from Schroeder et al. 1979.

Table 3. Performance of steers fed corn, barley, wheat, or oat silage[1]

	Silage					
			Wheat		Oat	
Item	Corn	Barley	Arthur	Sage	Trio	Lodi
n steers	18	18	18	18	18	18
ADG, kg	1.15^{a}	1.06^{ab}	0.94^{bc}	0.89^{c}	0.50^{d}	0.46^{d}
DMI, kg	8.68^{a}	8.87^{a}	8.52^{a}	8.73^{a}	6.64^{b}	6.69^{b}
Feed:gain	7.59^{a}	8.41^{a}	9.10^{a}	9.86^{a}	13.47^{b}	14.45^{b}

[1] Adapted from Oltjen and Bolsen 1980.

$^{a-d}$ Means in the same row with different superscripts are different ($P < 0.05$).

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RYE (*SECALE* CEREALE) SILAGE

General Description

Rye can be harvested for silage or for hay. Fall rye is winter hardy, tolerant of adverse soil, weather, and other environmental conditions, and the yields of rye often equal or exceed that of barley or wheat. The maturity of rye at harvesting plays an important role on the forage quality. As the plant matures the nutrient quality declines and the digestibility of the forage becomes poorer. The optimal stage to cut fall rye for nutrient content and animal acceptability is prior to the early milk stage to give forage comparable to other cereals. Inclusion levels of rye silage in ruminant rations are indeterminate due to variation in the quality of forage, although it can be used as the sole forage source.

Nutrient Composition and Behavior

Stephanyshyn-Cote (1994) compared the chemical composition of fall rye forage harvested at different maturities to that of barley silage. Rye was harvested and ensiled at flowering and again at mid-milk and barley ensiled at mid-dough stage. Table 1 shows the chemical composition of these feedstuffs. Overall, the two rye silages were more comparable to one another than either was to the barley silage, although there were significant differences between them. Crude protein, ash, and fibre was higher for silage harvested at flowering compared to that harvested in mid-milk stage. However, of the silages, barley had the highest crude protein, lowest fibre, and was intermediate in terms of ash. Similarly, mid-milk rye silage had the highest pH, followed by barley silage, then silage harvested at flowering. ADIN, as a percent of crude protein, was lowest for silage taken at flowering stage and highest for mid-milk rye silage, while intermediate for barley silage. Table 2 represents the nutrient composition and other characteristics of rye silage.

Table 1. Composition of fall rye and barley silages[1]

	Fall rye		Barley	
	Flowering	Mid-milk	Mid-dough	SEM
Moisture (%DM)	76.8^{b}	79.6^{a}	53.9^{c}	5.22
pH	3.91^{c}	4.24^{a}	4.08^{b}	0.06
CP (%DM)	8.43^{b}	7.91^{c}	8.84^{a}	0.19
Ash (%DM)	6.82^{a}	6.67^{c}	44.8^{b}	0.13
ADF (%DM)	47.9^{a}	44.8^{b}	64.9^{b}	3.23
NDF (%DM)	71.4^{a}	64.9^{b}	52.6^{c}	3.90
ADIN (%CP)	1.16^{c}	1.84^{a}	1.37^{b}	0.13

[1] Adapted from Stephanyshyn-Cote 1994.

[a-c] Means in the same row followed by different letters are significantly different ($P < 0.05$).

Table 2. Nutrient composition and characteristics of rye silage (100% DM basis)

Nutrient	Rye silage, vegetative[1]	Rye silage (n=45)[2]	SD
CP (%DM)	16.10	10.97	2.19
RDP (%CP)			
RUP (%CP)			
ADFIP (%DM)	0.9		
NDFIP (%DM)	1.9		
SP (%CP)			
NPN (%SP)			
CF %			
ADF %	34.9	39.83	2.64
NDF %	57.8		
Lignin (%DM)	4.5		
Cellulose (%DM)			
Starch (%)			
A kd (%/hr)			
B_1 kd (%/hr)			
B_2 kd (%/hr)			
TDN% (ruminants)	60.0	57.05	2.33
Energy coefficients (Mcal/kg)			
DE	2.72		
ME	2.08		
Nem	1.37		
NEg	0.79		
NEl	1.28		
Fat (EE) %	3.80		
Ash %	9.60		
Calcium %	0.43	0.33	0.07
Phosphorus %	0.42	0.22	0.05
Sodium %	0.05		
Magnesium %	0.16		
Copper (mg/kg)	9.00	7.60	1.67
Manganese (mg/kg)	63.00	37.82	5.30
Iron (mg/kg)	373.00		
Zinc (mg/kg)	32.00	17.68	0.33
Selenium (mg/kg)			

[1] NRC, Nutrient Requirements for Dairy Cattle 2001.

[2] Saskatchewan Feed Test Laboratory. Summary of feed analysis for 1990.

Feeding Value

Stephanyshyn-Cote (1994) compared the voluntary intake and nutrient digestibilities of steers fed the silages described above. The average voluntary intake of steers fed the three silages was very different among treatments. Steers fed the fall rye silage cut at the flowering stage consumed approximately one half (3.77 kg) that of the barley silage (7.01 kg), of which the intake was almost three times that of rye silage ensiled at mid-milk maturity (2.51 kg). *In vitro* and *in vivo* digestibilities are shown in Table 3. *In vitro* organic matter digestibility (IVOMD) was not significantly different among forages, although it was highest for the barley silage and lowest for the rye silage harvested at mid-milk. A similar pattern occurred in the *in vivo* OMD, although the absolute differences were significantly greater ($P < 0.05$). *In vivo* DMD, CPD, ADFD, and NDFD were all similar for barley silage and fall rye ensiled at the flowering stage, which were higher than those digestibilities of fall rye harvested at mid-milk maturity.

The *in sacco* organic matter disappearance was highest for barley silage, at all time intervals, relative to either rye silage. Organic matter disappearance at 0, 12, and 24 hours was similar between both rye silages, although it was higher for rye ensiled at flowering relative to mid-milk rye silage at 48 hours. The effective degradability of barley silage was highest followed by fall rye harvested at flowering and fall rye ensiled at mid-milk, respectively (data not shown).

The author concluded that as the maturity of rye silage increased, the intake and digestibility decreased, indicating that maturity has a lot of relevance in terms of feeding value. Stephanyshyn-Cote (1994) speculated that rye silage had a lower feeding value than barley silage mainly due to the higher proportion of cell wall contents present in fall rye compared to barley, which resulted in lower feed intake, and consequently a lower feeding value.

Table 3. *In vitro* and *in vivo* digestibility of fall rye and barley silage components (% dry matter basis)[1]

Treatment	*In vitro*	*In vivo*				
	OMD	OMD	DMD	CPD	ADFD	NDFD
Fall rye						
Flowering	46.2[a]	58.6[a]	56.2[a]	50.0[a]	51.0[a]	63.7[a]
Fall rye						
Mid-milk	43.8[a]	45.3[b]	41.3[b]	31.3[b]	30.8[b]	42.2[b]
Barley						
Mid-dough	49.6[a]	67.0[a]	66.1[a]	61.9[a]	55.3[a]	62.1[a]
SEM	1.36	3.12	3.49	4.38	3.80	2.99

[1] Adapted from Stephanyshyn-Cote 1994.

[a-c] Means in the same row followed by different letters are significantly different ($P < 0.05$).

In 1998, Hoffman et al. studied the nutritional value of perennial ryegrass silage (PRS) in lactating dairy rations. Eighteen cows were randomly assigned to one of two dietary treatments, consisting of alfalfa silage or PRS supplemented with a concentrate mix at 31.1% of dietary DM. Cows fed alfalfa silage produced 1.6 kg more milk per day than cows fed PRS (Table 4). Milk protein yield was lower for PRS fed animals relative to those fed alfalfa silage. Alfalfa silage and PRS had similar 4% FCM, which opposed the significant differences found between milk production. This occurrence is most likely attributed to the tendency for a higher milk fat percentage for cows fed PRS. Intakes of DM, CP, NDF, and ADF were all significantly lower for animals fed PRS relative to those fed alfalfa silage (Table 4).

The nutrient digestibility of alfalfa silage and PRS is shown in Table 5. The rate of passage was slower for PRS compared to alfalfa silage indicating that it had a longer digestive tract retention time. Consequently, the digestibilities of DM, OM, CP, and ADF were higher for PRS fed animals relative to those fed alfalfa silage. The digestibility of NDF tended to be higher for cows fed PRS compared to alfalfa silage fed animals, although the difference was not significant. The intake of PRS goes against most literature, which indicates that DMI is reduced because of NDF ruminal fill. In this particular trial cows fed PRS consumed less NDF and less DM than those fed alfalfa silage, therefore other factors led to the decreased DMI of PRS. The authors had done a previous study that suggested that perennial ryegrass contained slightly higher NDF than alfalfa, but that NDF was more digestible than that of alfalfa. This led the authors to speculate that perennial ryegrass would maintain equal milk production in lactating dairy cattle, compared to alfalfa.

Table 4. Lactation performance and intake characteristics of lactating cows fed diets containing alfalfa silage (AS) or perennial ryegrass silage (PRS)[1]

	Treatment diet			
	AS	PRS	SE	Effect (*P* value)
Yield, kg/d				
Milk	31.8	30.2	0.31	< 0.01
4% FCM	29.8	29.0	0.36	> 0.05
Fat	1.14	1.13	0.02	> 0.05
Protein	0.93	0.88	0.01	< 0.01
Composition, %				
Fat	3.61	3.76	0.06	> 0.05
Protein	2.96	2.93	0.02	> 0.05
Intake, kg/d				
DM	22.5	20.3	0.33	< 0.01
CP	4.6	4.0	0.07	< 0.01
ADF	5.7	5.3	0.08	< 0.01
NDF	8.0	7.5	0.12	< 0.05

[1] Adapted from Hoffman et al. 1998.

Table 5. Digestibility and dietary passage rates in lactating cows fed diets containing alfalfa silage (AS) or perennial ryegrass silage (PRS)[1]

	Treatment diet			
	AS	PRS	SE	Effect (*P* value)
Digestibility, % of intake				
DM	68.6	71.8	1.06	< 0.01
OM	70.5	73.5	1.03	< 0.01
CP	63.9	69.1	1.60	< 0.01
ADF	59.5	65.7	1.60	< 0.01
NDF	61.8	65.2	1.95	> 0.05
Rate of passage, %/h	4.86	4.05	0.171	< 0.01

[1] Adapted from Hoffman et al. 1998.

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TRITICALE SILAGE

General Description

With the increased marketability and acceptability of triticale as a grain its forage production is also increasing. Triticale can be planted as an annual forage crop for pasture, hay, or silage. Similar to most other cereal crops, the maturity of the triticale plays an important role on the feeding value of the forage. Usually the quality decreases just beyond the flowering stage of growth and should be cut prior to or at flowering to obtain optimal quality of forage. However, yields can be compromised when the triticale crop is harvested at too early a maturity, although it has comparable yields to that of barley and oats. The use of triticale silage in ruminant rations is not restricted, therefore it may be used as sole forage source. The nutrient composition and characteristics of triticale silage are shown in Table 1.

Feeding Value

Zobell et al. (1992) compared the performance of steers fed triticale or barley silage in combination with dry or high-moisture barley grain. Silage was fed at 25% of the total diet. The type of silage fed did not affect BW, ADF, DMI, and feed efficiency (Table 2). This suggests that triticale silage can be substitutes for barley silage, at 25% of the total ration, without causing adverse effects on steer performance.

McCartney and Vaage evaluated the feeding value of barley, oat, and triticale silage in 1994. A heifer feeding trial, consisting of 96 animals, showed that DMI was similar between oat and barley silage, which were higher than that of triticale silage (Table 3). In a similar study it was found that DMI of oat and barley silage were significantly different, although neither differed from the intake of triticale silage (Khorasani et al. 1993). The ADG was highest for those animals fed barley silage, intermediate for those fed oat silage, and lowest for heifers fed triticale silage. However, the feed efficiency of all silages was similar, indicating that the lower gains of animals fed triticale silage was a result of reduced feed intake.

The results of the sheep digestibility trial are shown in Table 4. The DMI of sheep fed barley was highest, intermediate for those fed oats, and lowest for sheep fed triticale silage. The dry matter digestibility was similar for oat and triticale silage, which were lower than that of barley silage. Sheep fed triticale and barley silage had similar OM and NDF digestibilities, which were greater than oat silage fed sheep. ADF digestibility was not influenced by forage type. A similar comparative study found that oat and triticale silage had similar total tract digestibilities for DM, OM, ADF, and NDF and only ADF digestibility was similar between triticale and barley silage (Khorasani et al. 1993). It was also found that including triticale in the diet of lactating dairy cattle increased milk protein percentage but did not alter milk production relative to animals fed oat, alfalfa, or barley silage. From the results, McCartney and Vaage (1994) concluded that the feeding value of triticale silage in general was poorer than that of barley or oat silage. The quality of triticale silage can be maximized by proper stage of harvest, which can produce a very acceptable forage source.

Table 1. Nutrient composition and characteristics of triticale silage (100% DM basis)[1]

Nutrient	Triticale silage, headed	Silage[2]
CP (%DM)	13.80	8.21
RDP (%CP)		
RUP (%CP)	1.0	
ADFIP (%DM)	2.2	
NDFIP (%DM)		
SP (%CP)		
NPN (%SP)		
CF %	39.6	33.8
ADF %	59.7	65.17
NDF %	5.8	
Lignin (%DM)		
Cellulose (%DM)		
Starch (%)		
A kd (%/hr)		
B_1 kd (%/hr)		
B_2 kd (%/hr)		
TDN% (ruminants)	57.2	62.0
Energy coefficients (Mcal/kg)		
DE	2.57	
ME	1.94	
Nem	1.25	
NEg	0.69	
NEl	1.18	
Fat (EE) %	3.80	
Ash %	9.70	
Calcium %	0.57	0.46
Phosphorus %	0.33	0.18
Sodium %	0.05	
Magnesium %	0.19	
Copper (mg/kg)	7.00	
Manganese (mg/kg)	66.00	
Iron (mg/kg)	404.00	
Zinc (mg/kg)	37.00	
Selenium (mg/kg)		

[1] NRC, Nutrient Requirements for Dairy Cattle 2001.

[2] Feed analysis report, University of Saskatchewan 1994.

In 1972, Fisher compared the feeding value of triticale and corn silage in the diets of lactating dairy cattle. It was found that corn silage had significantly greater feed intake, milk yield, and milk protein percentage. The type of silage did not affect milk fat and lactose composition. Although no significant, milk fat percentage tended to be higher for animals fed triticale silage relative to those fed corn silage, which was similar to results found by Khorasani et al. (1993). The nutrient digestibility of triticale and corn silage did not differ.

Table 2. Least square means for body weight (BW), average daily gain (ADG), dry matter intake (DMI), and feed efficiency (FE) in cattle fed different silages and cocentrates[1]

	Silage			Concentrate		
Traits[2]	Barley	Triticale	SEM	Barley	High-moisture barley	SEM
BW (kg)						
Start	266.7	265.2	1.8	264.8	267.2	1.8
28 d	298.4	295.2	1.8	297.1	296.5	1.8
56 d	328.9	325.1	2.7	326.2	327.9	2.7
84 d	361.6	355.4	3.4	359.8	357.2	3.4
ADG (kg/d)						
0 - 28 d	1.15	1.04	0.06	1.11	1.09	0.06
28 - 56 d	1.09	1.07	0.05	1.04	1.12	0.05
56 - 84 d	1.21	1.12	0.07	1.24	1.08	0.07
0 - 84 d	1.15	1.08	0.04	1.13	1.10	0.04
DMI (kg/d)	7.4	6.9	0.20	7.1	7.2	0.20
FE (kg/kg)	6.6	6.6	0.18	6.5	6.7	0.18

[1] Adapted from Zobell et al. 1992.

[2] Differences between means comparing silage and grain for each trait were not significant ($P > 0.05$).

Table 3. Performance of heifers fed barley, oat, and triticale silage[1]

Item	Barley	Oat	Triticale	SE
Number of animals	32	32	32	
Dry matter intake, kg/d	6.94[a]	6.58[a]	5.74[b]	0.17
Average daily gain, kg/d	0.65[a]	0.57[b]	0.49[c]	0.02
Feed:gain	10.7	11.6	11.7	0.30

[1] Adapted from McCartney and Vaage 1994.

[a-c] Means in the same row followed by different superscripts are different ($P < 0.05$).

Table 4. Dry matter intake and apparent nutrient digestibility of sheep fed barley, oat, or triticale silage[1]

Item	Barley	Oat	Triticale	SE
Dry matter intake, g/d	741.2[a]	616.9[b]	433.6[c]	27.7
Apparent digestibility, %				
DM	64.2[a]	58.3[b]	58.8[b]	1.1
OM	66.2[a]	61.1[b]	65.3[a]	1.0
NDF	52.0[a]	46.4[b]	54.0[a]	1.5
ADF	43.6	41.3	42.2	2.0

[1] Adapted from McCartney and Vaage 1994.

[a-c] Means in the same row followed by different superscripts are different ($P < 0.05$).

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WHEAT (*TRITICUM AESTIVUM*) SILAGE

General Description

Wheat silage is obtained from cutting green forage and preserving it by ensiling under oxygen limiting conditions. The length of the cut is important with respect to packing the material, with the optimum approximating ⅜ to ½ inch. As with all other cereal crops the maturity of the crop has an impact on the nutritional quality of the ensiled product. The optimal time to cut silage wheat is at the early to mid dough stage. Silage wheat yields are higher as the maturity of the plant increases, however the quality of the forage is compromised if harvested at a more mature stage. The quality of the forage determines the feeding value and, if poor, supplemental concentrate may be needed to account for losses in protein, energy, and other nutrients. While wheat is not widely grown for silage purposes, most is harvested to salvage a crop that has had hail. Table 1 illustrates the nutrient composition and characteristics of wheat silage.

Feeding Value

Bolsen et al. (1976) evaluated the growth performance of steers and lambs fed wheat, corn, or barley silage. Steers fed two different types of wheat silage consumed less dry matter, converted feed to gain poorer resulting in less weight gained than those fed corn silage (Table 2). Similarly lambs fed sorghum silage gained faster, consumed more dry matter, and converted feed to gain more efficiently than lambs fed the same two types of wheat silage at various stages of maturity (data not shown).

Christensen et al. (1977) evaluated the nutritive value of barley, wheat, oat, rye, and corn silages. It was found that wheat had the highest energy content and was similar to barley and oats in crude protein, which was significantly higher than that of rye or corn. Wheat contained more TDN and digestible energy than all other silages, but was not significantly different from that of barley. The authors concluded that wheat, barley, and oat silages were equivalent to the nutritive value of immature corn silage as energy and protein sources and were superior to spring rye as energy sources.

Table 1. Nutrient composition and characteristics of wheat silage (100% DM basis)

	Wheat silage			
Nutrient	Dough[a]	Early head[b]	Silage (n=28)[c]	SD
CP (%DM)	12.5	12.0	13.72	2.48
RDP (%CP)	81.0			
RUP (%CP)	19.0			
ADFIP (%DM)	1.0	1.0		
NDFIP (%DM)	3.38	1.5		
SP (%CP)	45.0			
NPN (%SP)	100.0			
ADF %		37.6	33.1	4.14
NDF %	60.7	59.9		
Lignin (%DM)	8.99	5.8		
Cellulose (%DM)				
Starch (%)				
A kd (%/hr)	275.0			
B_1 kd (%/hr)	50.0			
B_2 kd (%/hr)	10.0			
TDN%[2]	57.0	57.2	62.2	2.22
Energy coefficients (Mcal/kg)				
DE		2.55		
ME	2.06	1.91		
Nem	1.21	1.24		
NEg	0.64	0.67		
NEl		1.16		
Fat (EE) %	2.50	3.20		
Ash %	7.50	8.60		
Calcium %	0.44	0.38	0.51	0.30
Phosphorus %	0.29	0.29	0.27	0.05
Sodium %	0.04	0.07		
Magnesium %	0.17	0.16		
Copper (mg/kg)	9.00	7.00	6.46	
Manganese (mg/kg)	79.50	72.00	35.84	
Iron (mg/kg)	386.00	391.00		
Zinc (mg/kg)	28.00	27.00	19.34	
Selenium (mg/kg)	0.00			

[a] NRC, Nutrient Requirements for Beef Cattle 1996.

[b] NRC, Nutrient Requirements for Dairy Cattle 2001.

[c] Saskatchewan Feed Test Laboratory, summary of feed analysis 1988.

Table 2. Performance of steers fed corn silage or two types of wheat silage[1]

		Wheat silage	
Item	Corn	Blue-boy head	Parker-head
n. steers	21	21	21
Dry matter intake, kg/d	7.04[a]	6.56[b]	6.09[c]
Average daily gain, kg/d	0.87[a]	0.69[b]	0.64[c]
Feed:gain	8.09[a]	9.49[b]	9.48[b]

[1] Adapted from Bolsen et al. 1976.

[a-c] Means in the same row followed by different superscripts are different ($P < 0.05$).

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ALFALFA (*MEDICAGO SATIVA*) SILAGE

General Description

Traditionally alfalfa is made into hay, however, environmental conditions may lead to nutrient losses therefore, the cut alfalfa is used for ensiling. Alfalfa silage is made in a similar fashion to that of cereal silages. The moisture content of alfalfa should be at 65 to 70%, although low-moisture alfalfa can also be ensiled. As with most other forages, as alfalfa matures, the nutritive value declines, whereby the protein decreases and the fibre components increase. To obtain optimum yields and nutritive value alfalfa should be cut at early bloom. Alfalfa contains a higher amount of crude protein relative to cereal silages allowing alfalfa silage to be a better source of protein for ruminants. The energy content of alfalfa is similar to that of cereal silages, being close to the value of oat silage. The nutrient composition and characteristics of alfalfa silage are illustrated in Table 1.

Feeding Value

Okine et al. (1997) studied the effects of feeding alfalfa and bromegrass silage based diets with two different levels of concentrate on the feed intake and milk production and composition of late lactating cows. Milk production was not significantly affected by the source of forage fed (Table 2). However, diets with 50% concentrate had increased milk production and 4% fat corrected milk by 11% and 14%, respectively, relative to cows fed 35% concentrate. Fat, lactose, and protein yields were increased by 17%, 11%, and 11%, respectively when 50% concentrate was fed compared to 35% concentrate. The authors speculate that this may be due to the increased crude protein content and slightly higher DMI of cows fed 50% concentrate diets.

Mustafa et al. (2000) evaluated the effects of barley and alfalfa silage cut at early bloom and pea silage harvested at full-pod stage on ruminal nutrient degradabilities, and milk yields and composition of early lactating dairy cattle. Pea and alfalfa silage had similar soluble DM degradabilities, which were higher than that of barley silage (Table 3). The slowly degradable DM fraction was highest in barley compared to alfalfa or pea silage. The rate of DM degradation was highest in alfalfa silage, intermediate for pea silage, and lowest for barley silage. The EDDM was similar for pea and alfalfa silage, which was higher than that of barley silage. All silages had high soluble crude protein degradabilities, which left less than 20% of the crude protein in the slowly degradable fraction (Table 3). The rate of degradation of the slowly degradable crude protein fraction was not different among the three dietary treatments. The slowly degradable fraction of NDF was significantly different between alfalfa and barley silage, although neither differed from pea silage (Table 3). The rate of degradation and effective degradability of NDF for all silages followed a similar pattern, whereby it was highest for alfalfa silage, intermediate fro pea silage and lowest for barley silage.

Table 1. Nutrient composition and characteristics of alfalfa silage (100% DM basis)

	Alfalfa Silage				
Nutrient	Early Bloom[1]	Mid Bloom[1]	Full Bloom[1]	Early Bloom[2]	SD
CP (%DM)	19.5	17.0	16.0	19.3	0.1
RDP (%CP)	92.0	91.0	91.0		
RUP (%CP)	8.0	9.0	9.0		
ADFIP (%DM)	2.93	3.06	3.36	1.1	0.2
NDFIP (%DM)	5.27	5.44	5.92	1.37	0.5
SP (%CP)	50.0	45.0	40.0	71.3	0.4
NPN (%SP)	100.0	100.0	100.0	66.8	3.9
ADF %				28.7	1.8
NDF %	43	47	51	34.4	1.4
Lignin (%DM)	10	11	12	6.47	0.6
Cellulose (%DM)				5.8	1.1
Starch (%)				0.6	0.1
A kd (%/hr)	250.0	250.0	250.0		
B_1 kd (%/hr)	35.0	35.0	35.0		
B_2 kd (%/hr)	5.5	5.5	5.5		
TDN% (ruminants)[2]	63.0	58.0	55.0		
Energy coefficients (Mcal/kg)					
ME	2.28	2.1	1.99		
Nem	1.41	1.24	1.14		
NEg	0.83	0.68	0.58		
NEl					
Fat (EE) %	3.70	3.10	2.70	4.80	0.4
Ash %	9.50	9.00	8.00	10.1	0.4
Calcium %	1.32	1.74	1.74		
Phosphorus %	0.31	0.27	0.27		
Sodium %	0.02	0.16	0.16		
Magnesium %	0.26	0.33	0.33		
Copper (mg/kg)	12.10	11.10	11.10		
Manganese (mg/kg)	32.40	49.70	49.70		
Iron (mg/kg)	252.00	280.00	280.00		
Zinc (mg/kg)	19.50	40.70	40.70		
Selenium (mg/kg)	0.18	0.00	0.00		

[1] NRC, Nutrient Requirements of Beef Cattle 1996.

[2] Mustafa et al. 2000.

A study conducted by Khorasani et al. (1993) showed that whole tract digestibilities were higher in terms of DM, OM, CP, and ADF for alfalfa and barley silage compared to oat and triticale silage. The authors suggested that the higher DMI and lower ruminal fill of these feeds may have accounted for the higher nutrient digestibilities.

Mustafa et al. (2000) also evaluated milk yield and milk composition of early lactating cattle fed these three types of silage, as illustrated in Table 4. It was found that the type of silage had no effect on the total milk yield. These results are similar to that found by Khorasani et al. (1993), whereby the silage type did not affect milk production, 4% FCM, or milk fat percentage. Cows fed pea silage had milk that was lower in protein percentage and milk that tended to be higher in fat percentage relative to cows fed alfalfa silage, however these differences were not found between pea silage and barley silage. Cows fed pea silage had a higher milk fat yield than those cows fed alfalfa silage, although no differences were found between pea silage and barley silage in terms of milk fat yield. The type of silage did not affect milk lactose yield and percentage.

Table 2. Effect of forage:concentrate ratio and source of forage on intake, milk yield, and milk composition[1]

	Silage		Concentrate			Significance	
Parameter	Alfalfa	Brome	35%	50%	SEM	Silage	Concentrate
Intake (kg/d)							
Dry matter	14.6	15.7	14.5	15.8	0.60	NS[2]	0.07
NDF	5.1	6.2	5.8	6.0	0.30	<0.01	NS
Crude protein	2.8	2.3	2.3	2.7	0.12	<0.01	0.02
Yield (kg/d)							
Milk	10.8	10.5	10.1	11.2	0.49	NS	0.05
4% FCM	10.2	9.7	9.3	10.6	0.48	NS	0.04
Fat	0.39	0.37	0.35	0.41	0.019	NS	0.03
Protein	0.37	0.37	0.35	0.39	0.018	NS	0.07
Lactose	0.47	0.46	0.44	0.49	0.021	NS	0.04
Composition (%)							
Fat	3.58	3.47	3.51	3.54	0.038	0.03	NS
Protein	3.44	3.55	3.53	3.46	0.056	0.09	NS
Lactose	4.34	4.28	4.27	4.35	0.040	NS	NS

[1] Adapted from Okine et al. 1997.

[2] NS = Non-significant.

Table 3. Ruminal kinetic parameters and effective degradability of DM, CP, NDF, and starch of pea, alfalfa, and barley silage[1]

	Silage			
	Pea	Alfalfa	Barley	SEM
DM				
Soluble fraction, % of DM	50.4^{a}	49.2^{a}	40.4^{b}	0.41
Slowly degradable, % of DM	30.7^{b}	28.3^{b}	37.9^{a}	1.55
Rate of degradation, %/h	5.8^{b}	8.0^{a}	3.0^{c}	0.56
Lag time, h	2.9^{a}	1.2^{b}	0.0^{c}	0.30
Effective degradability[2]	67.0^{a}	66.4^{a}	53.9^{b}	0.51
CP				
Soluble fraction, % of DM	78.5	78.5	69.2	0.18
Slowly degradable, % of DM	15.9^{b}	14.9^{b}	18.5^{a}	0.22
Rate of degradation, %/h	9.7	9.0	11.6	1.24
Lag time, h	2.5^{a}	0.0^{c}	1.6^{b}	0.45
Effective degradability[2]	88.9^{a}	87.9^{b}	82.1^{c}	0.24
NDF				
Soluble fraction, % of DM	0.6^{b}	4.7^{a}	4.8^{a}	0.39
Slowly degradable, % of DM	51.5^{ab}	44.9^{b}	58.2^{a}	2.50
Rate of degradation, %/h	3.6^{b}	4.9^{a}	2.5^{c}	0.14
Lag time, h	1.0	0.0	0.4	0.32
Effective degradability[2]	23.5^{b}	27.0^{a}	21.9^{c}	0.48

[1] Adapted from Mustafa et al. 2000.

[2] Calculated assuming a ruminal outflow rate of 5%/h.

[a,b,c] Means in the same row with different superscripts differ ($P < 0.05$).

Table 4. Effect of feeding pea, alfalfa, or barley silage on intake, milk yield, and milk composition of dairy cows[1]

	Silage treatment			Contrast ($P <$)		
	Pea	Alfalfa	Barley	Pea vs alfalfa	Pea vs barley	SEM
Intake (kg/d)						
DM	28.6	27.5	26.0	0.23	0.063	0.6
CP	4.7	5.1	4.1	0.022	0.002	0.1
NDF	8.0	8.0	9.2	1.0	0.001	0.18
Milk yield (kg/d)						
Total	45.2	45.3	43.2	0.97	0.13	0.85
3.5% FCM	45.8	43.7	43.7	0.097	0.097	0.81
Fat	1.62	1.48	1.54	0.04	0.19	0.04
Protein	1.37	1.43	1.32	0.21	0.29	0.03
Lactose	2.03	2.03	1.95	0.99	0.25	0.04
Milk composition (%)						
Fat	3.65	3.36	3.65	0.072	0.98	0.1
Protein	3.03	3.16	3.08	0.003	0.19	0.02
Lactose	4.50	4.48	4.51	0.56	0.86	0.02
Total solids	12.24	12.14	12.34	0.42	0.4	0.08

[1] Adapted from Mustafa et al. 2000.

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BROMEGRASS SILAGE

General Description

Bromegrass is an introduced, cool season, perennial species grown on heavier soils of western Canada. Bromegrass can be harvested and ensiled giving rise to bromegrass silage. Typically, alfalfa is seeded with bromegrass and should be cut when alfalfa is in early bloom to obtain optimal yields and forage quality. The nutritive value of this type of silage is slightly lower than that of alfalfa silage alone. The nutrient composition of alfalfa-bromegrass silage is shown in Table 1.

Feeding Value

Okine et al. (1997) studied the effects of feeding alfalfa and bromegrass silage based diets with two different levels of concentrate on the feed intake and milk production and composition of late lactating cows. The dry matter intake was not affected by forage source (Table 2). The NDF intake was lower for cows fed alfalfa-based diets relative to bromegrass based diets, however concentrate level did not affect NDF intake. These results contradict most literature, which states that NDF content influences DMI (Khorasani et al. 1993). In this study, DMI remained similar between both forage sources, although NDF intake was higher with the bromegrass based diet, suggesting that DMI may be influenced more by the composition of NDF rather than the content. Milk production was not significantly affected by the source of forage fed (Table 2). However, diets with 50% concentrate had increased milk production and 4% fat corrected milk by 11% and 14%, respectively, relative to cows fed 35% concentrate. Fat, lactose, and protein yields were increased by 17%, 11%, and 11%, respectively when 50% concentrate was fed compared to 35% concentrate. The authors speculate that this may be due to the increased crude protein content and slightly higher DMI of cows fed 50% concentrate diets.

Table 1. Nutrient composition and characteristics of alfalfa-brome silage (100% DM basis)

Nutrient	Average
CP (%DM)[1]	16.12
RDP (%CP)	
RUP (%CP)	
ADFIP (%DM)	
NDFIP (%DM)	
SP (%CP)	
NPN (%SP)	
CF %	
ADF %[1]	53.32
NDF %	
Lignin (%DM)	
Cellulose (%DM)	
Starch (%)	
A kd (%/hr)	
B_1 kd (%/hr)	
B_2 kd (%/hr)	
TDN%[1]	53.34
Energy coefficients (Mcal/kg)[2]	
DE	2.90
ME	2.38
Nem	1.50
NEg	0.91
NEl	1.49
Fat (EE) %	
Ash %	
Calcium %[1]	1.21
Phosphorus %[1]	0.28
Sodium %	
Magnesium %	
Copper (mg/kg)[1]	8.80
Manganese (mg/kg)[1]	84.20
Iron (mg/kg)	
Zinc (mg/kg)[1]	19.37
Selenium (mg/kg)	

[1] Saskatchewan Feed Test Laboratory 1990.

[2] Christensen and Steacy 1985.

Table 2. Effect of forage:concentrate ratio and source of forage on intake, milk yield, and milk composition[1]

Parameter	Silage		Concentrate		SEM	Significance	
	Alfalfa	Brome	35%	50%		Silage	Concentrate
Intake (kg/d)							
Dry matter	14.6	15.7	14.5	15.8	0.60	NS[2]	0.07
NDF	5.1	6.2	5.8	6.0	0.30	<0.01	NS
Crude protein	2.8	2.3	2.3	2.7	0.12	<0.01	0.02
Yield (kg/d)							
Milk	10.8	10.5	10.1	11.2	0.49	NS	0.05
4% FCM	10.2	9.7	9.3	10.6	0.48	NS	0.04
Fat	0.39	0.37	0.35	0.41	0.019	NS	0.03
Protein	0.37	0.37	0.35	0.39	0.018	NS	0.07
Lactose	0.47	0.46	0.44	0.49	0.021	NS	0.04
Composition (%)							
Fat	3.58	3.47	3.51	3.54	0.038	0.03	NS
Protein	3.44	3.55	3.53	3.46	0.056	0.09	NS
Lactose	4.34	4.23	4.27	4.35	0.040	NS	NS

[1] Adapted from Okine et al. 1997.

[2] NS = Non-significant.

References

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CEREAL STRAWS AND CROP RESIDUES AS FORAGE

STRAW

General Description

Straw consists of the stems and leaves of plants after the removal of the seed. Straw is low in nutritive value with high fibre content, particularly lignin. The composition of straw varies and is dependent upon the stage of maturity at cutting and the environment that it is grown in. Of the cereal straws, oat straw is the most nutritive followed by barley, wheat, and rye straws. The nutritive value of straws can be improved by ammoniating the straw, which increases the protein and energy content of straws. Christensen and Steacy (1985) found that ammoniation of wheat, barley, and oat straws also increased the dry matter digestibility of the straws (Table 1). Straw that is low in nutritive value and cannot be improved by ammoniation is most often used for bedding. Straw of low nutritive value can be used for feed, but supplemental feeds should accompany straw to balance for energy, protein, minerals, and vitamins. Straw should be fed to animals that are not highly productive, such as wintering beef cattle. Cereal straw can be used up to 60% in brood cow rations and it has a much lower value compared to hay in growing rations. Older straw, usually one year or greater, tends to be more palatable and digestible than fresh straw.

Table 1. Dry matter digestibility of untreated and ammoniated wheat, barley, and oat straws[1]

	Dry Matter Digestibility (%)					
Straw (fed long)	DM	CP	Energy	TDN	CF	%DCP
Neepawa wheat						
Untreated	45.5	0.0	45.6	43.5	51.4	0.0
Ammoniated	53.3	40.6	49.7	47.9	63.9	2.0
Bonanza barley						
Untreated	48.8	7.1	43.0	40.0	55.0	0.3
Ammoniated	55.7	43.3	46.0	39.9	62.6	3.4
Random oats						
Untreated	48.7	0.0	45.4	43.3	57.2	0.0
Ammoniated	64.6	47.5	53.2	47.4	68.7	3.1

[1] Adapted from Christensen and Steacy 1985.

Reference

Christensen, D.A. and Steacy, G.M. 1985. A summary of the nutritive value of Saskatchewan silages and forages. Feed Evaluation Unit, University of Saskatchewan, Saskatoon.

BARLEY STRAW

General Description

Cereal straw makes up a significant portion of the total crop, which can be up to 50% of the crop weight. Studies have shown that beef cows can maintain body condition when fed up to 85% barley straw (Weienburger and Mathison 1977) and up to 80% barley straw has been used successfully in gestating beef cow diets (Kay et al., as quoted by Mathison et al. 1999). The inclusion of cereal straws in ruminant rations is limited by the low organic matter degradability and crude protein in comparison to other feedstuffs. When crop residues are used to maintain growing and lactating animals, their feeding value must be increased. This can be done by chemical or physical treatment of the straw to increase the digestibility and intake of the straw. The most common chemical treatments used to improve the nutritive quality of straws are ammonia, sodium hydroxide, and urea. The nutrient composition and characteristics of barley straw are illustrated in Table 1.

Feeding Value

It has been suggested that, similar to barley grain, the nutritive quality of barely straw differs among variety and genotype. This led Mathison and colleagues (1999) to evaluate differences in chemical composition and ruminal degradability of 25 different cultivars of barley straw with varying factors. These included examining differences among two and six-row types, covered and hulless barleys, and straw length. Mathison et al. (1999) found straws from two-row genotypes were approximately 5% more digestible than straw from six-row barley. Similarly, straw from covered barley had higher fibre contents than that of hulless varieties. Straws from semi-dwarf genotypes had significantly higher protein levels and less fibre content relative to taller varieties. Shorter, two-row hulless varieties of barley had higher effective degradability than taller, six-row covered cultivars. These results indicate that it would be useful to evaluate the type of barley grown when intending on using straw as feed.

Studies have shown that when excess barley straw was offered to growing cattle, the consumption did not increase, whereby the excess straw was refused (Velasquez et al. 1999).

Table 1. Nutrient composition and characteristics of barley straw (100% DM basis)

Nutrient	Average	SD
CP (%DM)[1]	6.24	2.44
RDP (%CP)[2]	30.0	
RUP (%CP)[2]	70.0	
ADFIP (%DM)[2]	2.86	
NDFIP (%DM)[2]	3.3	
SP (%CP)[2]	20.0	
NPN (%SP)[2]	95.0	
ADF %[1]	48.71	4.54
NDF %[2]	72.5	
Lignin (%DM)[2]	9.97	
Hemicellulose (%DM)[3]	44.0	
Cellulose (%DM)[3]	37.0	
A kd (%/hr)[2]	250.0	
B_1 kd (%/hr)[2]	30.0	
B_2 kd (%/hr)[2]	3.0	
TDN %[1]	46.55	
Energy Coefficients (Mcal/kg)[1]		
DE	1.98	
ME	1.63	
NEm	0.98	
NEg	0.06	
NEl	0.98	
Fat (EE) %[2]	1.90	
Ash %[2]	7.50	
Calcium %[1]	0.32	0.08
Phosphorus %[1]	0.12	0.07
Sodium %[2]	0.14	
Magnesium %[2]	0.23	
Copper (mg/kg)[2]	5.40	
Manganese (mg/kg)[2]	16.00	
Iron (mg/kg)[2]	200.00	
Zinc (mg/kg)[2]	7.00	
Selenium (mg/kg)[2]	0.00	

[1] Saskatchewan Feed Test Laboratory, summary of feed analysis 1990.

[2] NRC, Nutrient Requirements for Beef Cattle 1996.

[3] NRC, United States-Canadian Tables of Feed Composition 1982.

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OAT STRAW

General Description and Nutrient Composition

Oat straw, like most other cereal straws, can be used in the rations of ruminant animals. Of the cereal straws, oats has the highest feeding value and is most preferred by producers, although it is typically lower in crude protein than barley straw. The energy level and mineral content of oat straw is comparable to all other cereal straws. Oat straw does not provide sufficient amounts of nutrients to meet cattle requirements, and therefore should not be fed alone. Consequently it must be supplemented with additional protein, energy, and minerals to provide a balanced ration. The nutritional value of oat straw can be improved through chemically or physically treating the straw, whereby the energy, protein, digestibility, and intake are increased. The nutrient composition and characteristics of oat straw are presented in Table 1.

Feeding Value

As previously mentioned, chemically treating oat straw can be beneficial with regards to improved nutrient composition. Hai and Sing (1993) fed cattle urea treated oat straw and urea-supplemented oat straw to evaluate which performed better in cattle rations. They found that oat straw supplemented with urea-molasses or treated with urea alone met the energy and protein requirements of cattle.

Hai and Singh (1994) conducted a similar study whereby they treated oat straw with 0, 2, 3, or 4% urea and 40% water, which was later ensiled. The chemical composition and nutrient degradability of this ensiled product was determined. As the level of urea increased the crude protein content increased and the fibre components decreased. Due to the decreasing lignin of the straw, the rumen degradability of fibrous components was improved. It was found that animals responded best to straw treated with 4% urea.

Aronen (1990) compare the nutritive value of ammonia-treated oat straw and low or high urea treated oat straw. Amoniation of the straw increased the digestibility of organic matter, crude protein, and crude fibre when fed to sheep. However, urea treatment only improved the crude protein digestibility. The feeding value of low or high urea treated oat straw was only slightly improved from untreated oat straw, although the feeding value of ammonia treated straw was 14% higher. The results of this study clearly indicated that ammonia treatment of oat straw was superior to that of urea treatment.

Aronen et al. (1994) supplemented oat straw with various levels of concentrate (2, 3, 4, or 5 kg) to evaluate the optimum amount to use in cattle rations. It was found that as the concentrate in the ration increased, the intake of roughage was decreased, although total dry matter intake remained the same. Average daily gains of cattle were increased as the concentrate level in the diet increased. This study shows the importance on performance when supplementing a low-quality feedstuff, such as oat straw, with additional energy and protein.

Table 1. Nutrient composition and characteristics of oat straw (100% DM basis)

Nutrient	Average	SD	Ammoniated oat straw[4]
CP (%DM)[1]	5.86	1.87	
RDP (%CP)[2]	55.0		
RUP (%CP)[2]	45.0		
ADFIP (%DM)[2]	2.86		
NDFIP (%DM)[2]	3.30		
SP (%CP)[2]	20.0		
NPN (%SP)[2]	95.0		
ADF %[1]	47.63	4.26	
NDF %[2]	74.4		
Lignin (%DM)[2]	14.88		
Cellulose (%DM)[3]	40.0		
A kd (%/hr)[2]	250.0		
B_1 kd (%/hr)[2]	30.0		
B_2 kd (%/hr)[2]	3.0		
TDN %[1]	46.71	4.80	
Energy Coefficients (Mcal/kg)[4]			
DE	1.91		2.09
ME	1.57		1.71
NEm	0.73		0.87
NEg	0.20		0.33
NEl	0.94		1.04
Fat (EE) %[2]	2.20		
Ash %[2]	7.80		
Calcium %[1]	0.29	0.08	
Phosphorus %[1]	0.12	0.06	
Sodium %[2]	0.42		
Magnesium %[2]	0.17		
Copper (mg/kg)[1]	2.93	0.88	
Manganese (mg/kg)[2]	31.00		
Iron (mg/kg)[2]	164.00		
Zinc (mg/kg)[1]	5.44	0.37	
Selenium (mg/kg)[2]	0.00		

[1] Saskatchewan Feed Test Laboratory, summary of feed analysis 1990.

[2] NRC, Nutrient Requirements for Beef Cattle 1996.

[3] NRC, United States-Canadian Tables of Feed Composition 1982.

[4] Christensen and Steacy 1985.

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RYE STRAW

General Description and Nutrient Composition

Rye straw, a residue from the production of rye grain, can be used as forage in the diets of ruminant animals. Rye is not grown abundantly in western Canada, consequently rye straw is not used as extensively in ruminant rations and not much data is available on the feeding value of rye straw. The nutrient content of rye straw is comparable to that of other cereal crop residues, although it tends to be lower in nutritive value than oat or barley straws and more similar to wheat. As with most other cereal straws, the cell wall of rye straw is highly lignified and can constitute up to 80% of the dry matter. Non-structural carbohydrates and proteins are found in relatively lower proportions; however, the mineral content of rye straw can be quite high. The protein content of rye straw is generally lower than that of barley or oat straw and is dependent upon the soil conditions, environmental conditions, and the time of harvest. Typically, cereal crops are grown for the purpose of harvesting the grain, whereby the straw will be at its most mature state. Chemical or physical treatment of the rye straw can be used to improve the nutritional value of this mature straw. The nutrient composition and characteristics of rye straw are illustrated in Table 1. The straw of fall rye is less palatable than other cereal straws due to its stemmy nature.

Feeding Value

As mentioned previously, the cell wall of rye straw is highly lignified. Sun et al. (2000) evaluated the effectiveness of treating rye straw with hydrogen peroxide on the destructuring of lignin. It was found that this type of treatment did not affect the structure of lignin in rye straw and was not useful in reducing the lignin content of rye straw.

In 1980, Aines et al. evaluated the feeding value of ground rye straw ensiled with manure from cattle fed high maize concentrate diets or high maize roughage diets. The ensiled product was treated with sodium hydroxide (NaOH). It was found that the source of manure affected the ensiling characteristics, especially in the NaOH treated silage. In a subsequent study by Aines et al. (1982) it was shown that untreated silage had more desirable fermentation characteristics than NaOH treated silage. In a lamb metabolism trial it was found that the NaOH treatment decreased crude protein, ether extract, NDF, and hemicellulose contents, however, dry matter, organic matter, crude fibre, hemicellulose, and cellulose digestibilities were improved. Crude protein and ether extract digestibilities were reduced when the silage was treated with NaOH, as was found in 1980 by Aines et al.

Table 1. Nutrient composition and characteristics of rye straw (100% DM basis)

Nutrient	Average[1]
CP (%DM)[1]	3.0
RDP (%CP)[2]	
RUP (%CP)[2]	
ADFIP (%DM)[2]	
NDFIP (%DM)[2]	
SP (%CP)[2]	
NPN (%SP)[2]	
CF %[1]	43.1
ADF %[1]	
NDF %[1]	
Lignin (%DM)[2]	
Cellulose (%DM)[7]	
A kd (%/hr)[2]	
B_1 kd (%/hr)[2]	
B_2 kd (%/hr)[2]	
TDN %[1]	44.0
Energy Coefficients (Mcal/kg)[3]	
DE	1.94
ME	1.51
NEm	0.96
NEg	0.01
NEl	0.96
Fat (EE) %[2]	1.70
Ash %[2]	5.00
Calcium %[1]	
Phosphorus %[1]	
Sodium %[2]	
Magnesium %[2]	
Copper (mg/kg)[1]	
Manganese (mg/kg)[2]	
Iron (mg/kg)[2]	
Zinc (mg/kg)[1]	
Selenium (mg/kg)[2]	

[1] NRC, United States-Canadian Tables of Nutrient Composition 1982.

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TRITICALE STRAW

General Description

Straw from triticale, grown for the harvest of grain, can be utilized in the diets of ruminants. As with all other cereal straws, chemical or physical treatment of triticale straw can be used to improve its feeding value with great success. Gralak et al. (1994) found that irradiation of triticale straw improved the chemical composition and treatment with sodium hydroxide increased dry matter degradability in the rumen. Triticale forage has a similar crude protein content to that of other cereal forages and typically has lower cell wall constituents relative to oat, wheat, and rye forage. Studies have shown that triticale forage has the highest TDN concentration compared to that of barley, wheat, rye, or oat forage at 88.6 percent (Bishnoi and Patel 1979).

Feeding Value

Saki et al. (1997) compared the nutritive value of triticale straw to that of triticale straw treated with 5% urea. It was found that the application of urea reduced dry matter and crude fibre while increasing crude protein and ash content. Urea treatment also served to increase the nutrient digestibility of triticale straw.

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WHEAT STRAW

General Description and Nutrient Composition

Wheat straw is the most abundant cereal straw in western Canada, as wheat is the leading cereal crop grown in this region. The feeding value of wheat straw is usually poorer than that of oat or barley straw and more similar to rye straw. Spring wheat generally has a higher crude protein content and dry matter digestibility than winter wheat. The crude protein of wheat straw is generally lower and the crude fibre, particularly ADF, is higher than that of oat or barley straw. The energy and mineral content of wheat straw is comparable to other cereal straws. Chemically treating wheat straw with anhydrous ammonia improves its nutritive value to reach levels close to, or superior to, that of oat or barley straw. The nutrient composition and characteristics of wheat are shown in Table 1. Wheat straw can also be used as bedding for all classes of livestock and poultry.

Feeding Value

Naseeven and Kincaid (1992) evaluated the effects of feeding chemically treated wheat straw to beef heifers on the feeding value and acceptability of the straw. It was found that the DMI was not significantly increased between groups fed ammoniated straw and those fed untreated straw, although it significantly improved the average daily gain (510 g vs. 347 g). Heifers fed ammonia and sulfur dioxide treated straw consumed more feed and had higher gains relative to those animals fed urea treated straw. Animals fed ammonia and sulfur dioxide treated straw in combination with hay had similar feed intakes and gains compared to those fed bromegrass hay. This data indicated that the feeding value of wheat straw can be improved with chemical treatment, which may lead to increased animal performance.

Horton et al. (1979) evaluated the effects of pelleting and treating wheat straw with ammonia or NaOH on the nutritive value for finishing steer rations. Rations included levels of 40% Neepawa wheat straw. Table 2 illustrates the performance characteristics of cattle fed these straws. The intake of straw was increased through ammoniation, although NaOH treatment did not improve intake. The consumption of the feed and average daily gain was increased when the ration was pelleted, regardless of chemical treatment. Ammoniation and NaOH treatment of wheat straw increased the digestibility, however, cattle fed these straws had similar gains as those consuming untreated pelleted straw.

Table 1. Nutrient composition and characteristics of wheat straw (100% DM basis)

Nutrient	Average	SD	Ammoniated wheat straw[4]
CP (%DM)[1]	5.31	2.07	
RDP (%CP)[2]	31.0		
RUP (%CP)[2]	69.0		
ADFIP (%DM)[2]	2.28		
NDFIP (%DM)[2]	2.63		
SP (%CP)[2]	20.0		
NPN (%SP)[2]	95.0		
ADF %[1]	53.97	3.60	
NDF %[2]	78.9		
Lignin (%DM)[2]	12.99		
Cellulose (%DM)[3]	39.0		
A kd (%/hr)[2]	250.0		
B_1 kd (%/hr)[2]	50.0		
B_2 kd (%/hr)[2]	8.0		
TDN %[1]	44.00	5.25	
Energy Coefficients (Mcal/kg)[4]			
DE	1.92		2.11
ME	1.57		1.73
NEm	0.73		0.89
NEg	0.20		0.35
NEl	0.95		1.05
Fat (EE) %[2]	2.10		
Ash %[2]	7.70		
Calcium %[1]	0.23	0.06	
Phosphorus %[1]	0.09	0.04	
Sodium %[2]	0.14		
Magnesium %[2]	0.12		
Copper (mg/kg)[1]	2.56		
Manganese (mg/kg)[1]	27.75		
Iron (mg/kg)[2]	157.00		
Zinc (mg/kg)[1]	8.00		
Selenium (mg/kg)[2]	0.00		

[1] Saskatchewan Feed Test Laboratory, summary of feed analysis 1990.

[2] NRC, Nutrient Requirements for Beef Cattle 1996.

[3] NRC, United States-Canadian Tables of Feed Composition 1982.

[4] Christensen and Steacy 1985.

Table 2. Effect of treating neepawa wheat straw with anhydrous ammonia and sodium hydroxide (NaOH) and pelleting on performance of cattle[1]

	Untreated		Ammoniated straw		NaOH + pelleted straw	
	Chopped	Pelleted	Chopped	Pelleted	Untreated	Ammoniated
DMI, kg/d	9.87	10.89	10.78	11.52	11.24	11.35
ADF, kg/d	0.92[a]	1.13[b]	1.03[b]	1.13[b]	1.13[b]	1.15[b]
Feed:gain	10.73	9.62	10.47	10.19	9.95	9.87

[1] Adapted from Horton et al. 1979.

[a,b] Means in the same row followed by different superscripts are significantly different ($P < 0.05$).

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CROP RESIDUES AS FORAGE

Legume straws, such as pea and bean straw are richer in protein and some minerals than cereal straws. Legume straw is more difficult to dry than cereal straws because of the thick fibrous nature of the stems, leading to moister straw. Legume straws with high moisture may tend to mould more readily than cereal straws. Canola straw is of little feeding value as it contains relatively low protein and energy (Lardy and Anderson 1999). Tables 1 and 2 show the nutritive value of various legume straws along with flax straw compared to wheat straw.

Mann et al. (1988) conducted a steer digestibility trial, whereby ammoniated and non-ammoniated flax and lentil straw were examined. Flax straw was evaluated over two years and lentils in one year. The in vivo digestibility of flax straw was much lower in 1986 relative to 1987, but it was significantly improved through ammoniation, as was lentil straw (Table 3). As a result of the increased digestibility by ammoniating flax and lentil straw, animals consuming these diets increased intakes and supported higher average daily gains compared to animals fed non-ammoniated lentil and flax straws.

Table 1. Nutrient content of various straws (100% Dry matter basis)[1]

Nutrient (%DM)	Lentil straw	Pea straw	Flax straw	Wheat straw
Protien	6.40	6.40	2.90	3.90
TDN	46.0	46.0	39.5	42.5
Calcium	0.65	0.60	0.30	0.28
Phosphorus	0.20	0.19	0.20	0.11

[1] Saskatchewan Feed Testing Laboratory, University of Saskatchewan.

Table 2. Chemical composition of treated and untreated straws (% dry matter)[1]

Feedstuff	CP		ADF		NDF		ADL	
	1986	1987	1986	1987	1986	1987	1986	1987
Flax straw	2.8	3.6	58.7	61.5	73.8	76.6	10.6	12.8
NH_3 flax straw	8.1	8.1	57.4	61.9	71.9	80.4	10.5	14.6
Lentil straw		6.6		41.8		64.0		9.4
NH_3 lentil straw		17.1		36.4		56.5		7.9

[1] Mann et al. Termuende Research Station; Management, production, and research report 1988.

Table 3. The *in vitro* and *in vivo* organic matter digestibility of untreated and ammoniated straws[1]

Feedstuff	Organic Matter Digestibility			
	in vitro		*in vivo*	
	1986	1987	1986	1987
Flax straw	35.2	33.9	33.9^{b}	64.2^{a}
NH_3 flax straw	46.3	41.0	58.4^{cd}	65.2^{a}
Lentil straw		45.1		44.5^{cd}
NH_3 lentil straw		47.9		51.6^{bc}

[1] Mann et al. Termuende Research Station; Management, production, and research report 1988.

$^{a-d}$ Means in the same column followed by different superscripts are significantly different ($P<0.05$).

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